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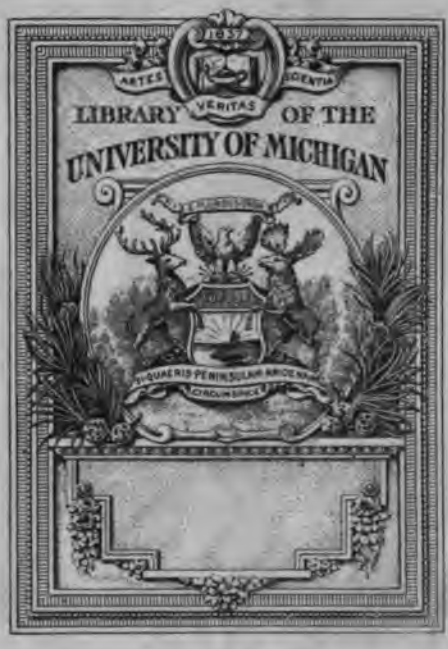
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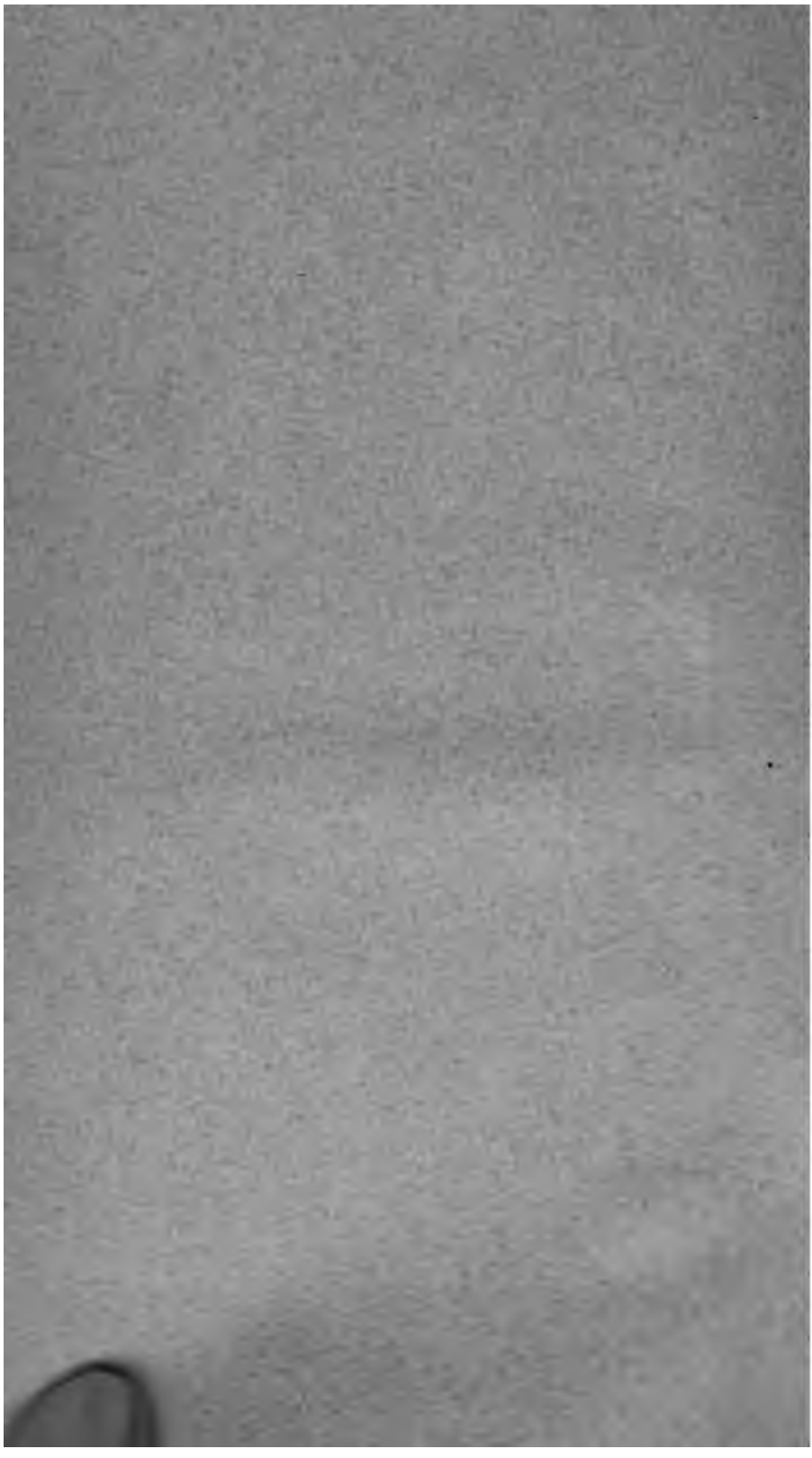

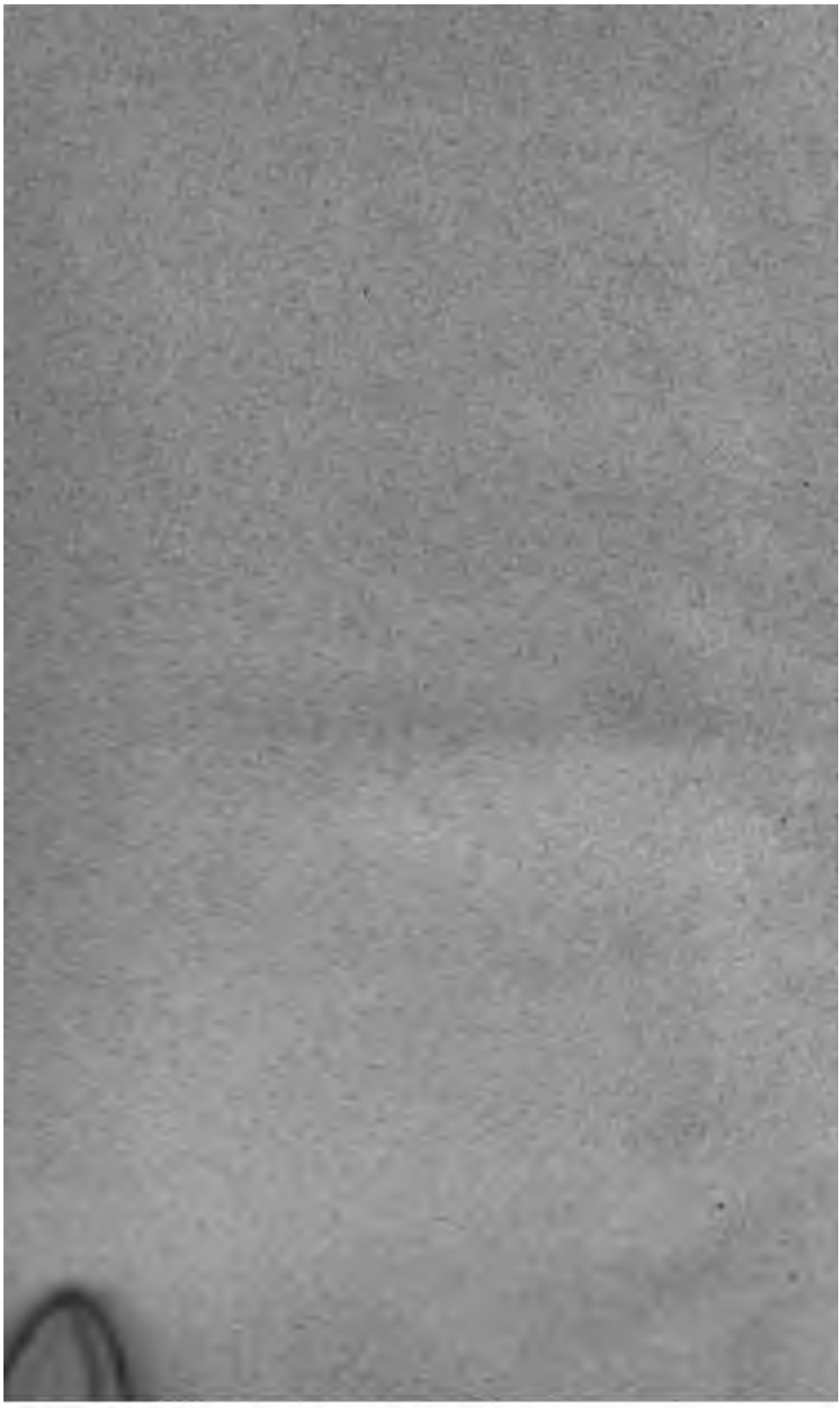

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NOTE.

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Manchester Memoirs, Vol. xlii (1898), *No.* 1.

I. Notes on a Collection of Hymenoptera from Greymouth, New Zealand, with descriptions of New Species.

By PETER CAMERON.

[*Communicated by J. Cosmo Melvill, M.A., F.L.S.*]

Received October 12th. Read October 19th, 1897.

The species of Hymenoptera enumerated and described in this paper were collected in the vicinity of Greymouth, New Zealand, by the late Mr. Richard Helms, whose assiduous labours have added so much to our knowledge of the Insect Fauna of New Zealand, and who, after his departure therefrom, did equally good work in investigating the Natural History of Australia.

Our earliest information on the Hymenoptera we owe to Fabricius, whose types are now in the Banksian Cabinet in the British Museum; then, at a long interval, followed Francis Walker, who described some *Chalcididæ* collected by Darwin during the memorable voyage of the "Beagle," in his "Monographia Chalciditum," 1839; F. Smith, in his Catalogue of Hymenoptera in the British Museum; and Mayr and Sichel in "Reise der Novara," 1867. Then in 1876 came F. Smith's important papers, "Descriptions of New Species of Hymenopterous Insects of New Zealand, collected by C. M. Wakefield, Esq., principally in the neighbourhood of Canterbury" (*Trans. Entom. Soc.* 1876, pp. 473 487); "Descriptions of Three New Species of Hymenoptera (*Formicidæ*) from New Zealand," *l.c.* pp. 489-

492 ; followed in the same *Transactions*, 1878, pp. 1-7, by "Descriptions of New Species of Hymenopterous Insects from New Zealand, collected by Prof. Hutton, at Otago." Mr. W. F. Kirby (*Trans. Entom. Soc.* 1881, pp. 35-50) continued Mr. Smith's work with "A list of the Hymenoptera of New Zealand," and, *l.c.* 1883, pp. 199-202, contributed "Notes on New or little-known Species of Hymenoptera, chiefly from New Zealand."

In *Bull. Soc. Entom. Ital.*, xvi., 1884, Signor Gribodo described *Agenia Brouni* ; in *Trans. New Zealand Inst.*, xvii., pp. 158 and 159, Mr. Colenso described *Rhyssa clavula* and *Lissonota multicolor*; in *Manchester Memoirs*, 1887-8-9, I described five new species from Greymouth ; in *Entom. Mon. Mag.*, iii (2), p. 275, the Rev. T. A. Marshall described *Tanyzonus bolitophilæ* [=*Betyla fulva* Cam.] which, with a *Diapria* described by Mr. Maskell (*Trans. New Zealand Inst.*, xi., p. 230), the catalogue of Captain Hutton, and the descriptions of *Hubertia*, &c., by Prof. Forel in *C. R. Soc. Entom. Belg.*, 1890, completes our narrative of the history of the literature of New Zealand Hymenoptera.

Mr. Kirby in his list enumerated 81 species, from which two may safely be deducted—one *Ophion luteus* Fab., a common European species recorded by Fabricius, doubtless in error, one of the native species having been probably mistaken for it ; and *Blennocampa adumbrata* Klug, the common European slug-worm, described by Mr. Kirby as *Monostegia antipoda*. This leaves 79 as the total number known as inhabitants of the islands in 1881 ; add thereto five (one species, *Priocnemis Pascoei* Kirby, was described in error) recorded in Kirby's paper of 1883, Gribodo's *Agenia Brouni*, Colenso's *Rhyssa* and *Lissonota*, my three specimens described in 1888, the two in 1889, and the 34 new species now described give us a total of 121 species known from New Zealand.

This undoubtedly marks a gratifying increase of knowledge since 1881 ; but I am certain that, if the islands were to be again explored by a naturalist of the calibre of Mr. Helms, the list might easily be doubled, particularly if unworked localities were investigated.

It is more than probable that many of the species are very local in their distribution, as is the case with Lepidoptera and Coleoptera. On this point the following remarks of Mr. E. Meyrick (*Proc. Entom. Soc.* 1883, p. 29) throw some light on the peculiarities of the New Zealand Insect Fauna. "The islands were composed partly of bare mountain ranges, partly of low-lying forest. The mountains, although very bleak and shelterless, had an extensive and varied fauna, fresh species of insects occurring on every mountain visited ; the genus *Crambus*, for example, was represented by a variety of species, for which there seemed to be no special reason. On the other hand, the forests, which comprised a remarkable number of trees and shrubs apparently well suited for food, were strangely deficient in insects, and further, the same species occurred nearly throughout the islands. It appeared, in fact, that a vast number of situations suitable for insects was not utilised. This was the case with the Lepidoptera and Coleoptera and probably with other insects." The parasitic species are probably not very numerous, their places being taken by the parasitic Diptera. At present the Diptera slightly exceed the Hymenoptera in number of species.

As regards the affinities of the New Zealand species the relationship to Australia is not very great. It is indicated on the one hand by the presence of the Australian genera *Lamprocolletes*, *Dasycolletes*, *Leioproctus* and *Rhagigaster* ; and by species common alike to the Islands and to Australia or Tasmania. These species are *Leioproctus imitatus* Sm. found in Australia, *Lamprocolletes*

obscurus Sm. in Tasmania, *Prosopis vicina* Sichel in Tasmania, and the Ichneumon "*Rhyssa*" *semipuncta* Kirby, which seems to be a common Australian species.

Of the Aculeates, the Bees and *Pompilidæ* are the most numerous in species. The latter appear to be, judging from the collecting of Mr. Helms, the most numerous in individuals, as they are the most striking in size, form, and coloration. Their great abundance would seem to indicate a rich and varied arachnid Fauna; for the *Pompilidæ* store their nests with spiders. Next to the *Pompilidæ*, the family most numerous in species is the *Larridæ*, which prey on *Orthoptera*. Among the parasitic forms the genus *Ichneumon* possesses the greatest number of species, some of which are very large and handsome creatures.

Although, of course, there can be no genetic relationship between the Hymenopterous Fauna of New Zealand and the Hawaiian Islands, yet a comparison between the two brings out some very interesting features. *Pison* is not a large genus, but it is very widely spread over the globe. It is not uncommon in Australia, is represented in the Malay Archipelago, by one species in Tahiti, and by two in Hawaii. *Prosopis*, a bee genus, has twelve species in Hawaii, as against seven in New Zealand, it is common in Australia and is of almost world-wide distribution. The *Larridæ* are fairly well represented in New Zealand, but are quite absent from Hawaii. The *Crabronidæ* again are much more numerous in the last mentioned locality—ten species as against four in New Zealand, the two latter belonging to a group (*Rhopalum*) not found in Hawaii at all. It is, however, in the dominant group in each of the localities where we find the most remarkable distinction. The characteristic family in New Zealand is the *Pompilidæ*, in Hawaii the *Vespidæ*, neither being represented in the other islands; both families, moreover, being common

in Australia and Tasmania—why this should be so it is difficult to understand. The absence of *Pompilidæ* in Hawaii may be owing to the scarcity of spiders there: but on this point I have no information. The absence of the *Odynerida* in New Zealand cannot be owing to the absence there of their food, for it is as common as, if not more abundant than, it is in the Sandwich Islands. The absence of *Tachytes*, &c., in the Hawaii Islands may be caused by there being no crickets living there.

The paucity of *Formicidæ* in species is remarkable. All the species are endemic, two of the genera being peculiar. I cannot, however, understand how, while in the Sandwich Islands there are at least five ants of almost world-wide distribution, *e.g.*, *Ponera contracta*, *Prenolepis longicornis*, *Tetramorium guineense*, none of them should have been recorded from New Zealand, where one would think the environment is eminently suitable and the commercial intercourse with other regions even more extensive.

As respects the species added by Mr. Helms to the Fauna, the most noteworthy are those belonging to the genera *Dicoelotus*, *Hemiteles*, *Chorinæus*, *Bassus*, *Ascogaster*, *Meteorus*, and *Alysia*, those genera not having been previously recorded. Of the species, *Ichneumon hersilia*, which differs markedly from the others in structure, is perhaps the most interesting.

TENTHREDINIDÆ.

No native species of this family is known; but the common European slug-worm of the pear (*Blennocampa adumbrata*) has been introduced, and recorded by Captain Hutton in his list as *Blennocampa cerasi*; by Mr F. Smith (*Trans. Entom. Soc.*, 1876, p. 474) as *Blennocampa adumbrata* Klug; and it has been described by Mr. W. F. Kirby (*Trans. Entom. Soc.*, 1881, p. 50) as a new species under the

name of *Monostegia antipoda*. *Monostegia* is not a valid genus, being founded on a character which is not constant even in the same species. Thus *Eriocampa adumbrata* is frequently found with only one median cellule in the hind wings, instead of the normal two. Mr. Helms sends it from Greymouth.

SIRICIDÆ.

XIPHIDRIA DECEPTA.

Derecyrta deceptus Sm., *Trans. Entom. Soc.*, 1876, p. 474, pl. 4, f. 6.

Xiphidria flavopicta Sm., *l.c.* 1878, p. 1.

As figured by Smith this species is shown of a much too uniform colour; the eye orbits, the lines on vertex, the face and edge of the pronotum are clear pale yellow; the mesonotum dark ferruginous, suffused with black; the basal four segments of the abdomen clear reddish, and the legs bright pale yellow. On the other hand, the thorax above frequently wants the yellow marks found in the type, the scutella, for example, not being differently coloured from the mesonotum, while again the wings are clear, not fulvo-hyaline. I suspect, however, that my three examples are immature, a circumstance which makes wood-feeding insects have the markings and colour less distinct; although it must be said that the yellow on the head and the rufous colour on the abdomen are bright enough in my two males, the ♀ being coloured more as in Smith's figure.

ICHNEUMONIDÆ.

ICHNEUMON.

A. Scutellum largely elevated, oblique, its top depressed in the middle, the sides rounded; the tubercles largely projecting, much larger than usual, somewhat triangular, but with the apex rounded; the median segment not tuberculate nor spined.

ICHNEUMON HERSILIA, *sp. nov.*

Rufus, thorace nigro et albo-maculato; pedibus rufis; alis fulvo-hyalinis, stigmate nigro. ♂. Long. 11 mm.

Head rufous; the inner orbits narrowly below, broadly above, and the sides of the clypeus, yellow; the ocellar region, the front, and the occiput, black; the vertex bare; the face covered with short fuscous hair; the mandibles rufous, the teeth black; the face roundly projecting in the middle, strongly but not closely punctured; the hollowed front finely transversely striated; the palpi rufous. Prothorax black, broadly rufous above; the mesonotum has the sides and base, broadly in the middle, black; the rest rufous, with a large yellow mark at the apex. The scutellum yellow, a rufous splash at the base; its height is nearly equal to its width at the bottom; the basal keels are curved and reach to the middle; the top is irregularly divided, one lobe being wider than the other. The median segment is gradually rounded to the apex; the areæ distinct; the supramedian widely separated from the base of the segment, longer than broad, a little narrowed towards the base, which is rounded; the sides straight; the posterior median black, transversely striated; the other areæ smooth and shining; the base of the segments broadly black; the sides are also edged with black; and, in front of the coxæ, there is a large yellow mark touching the keel. The propleuræ broadly black in the middle; the mesopleuræ at and including the tubercles white, the lower part rufous, with a large white mark in the centre, and the sternum is rufous; there is a broad black oblique band in the middle; and the apex is black, narrowly so on the lower side; the breast black in front. Legs entirely rufous, as is also the abdomen. The stigma and nervures black; the areolet almost triangular, the nervures being

narrowed at the top, where it is in width less than the space bounded by the recurrent and the second transverse cubital nervures; the transverse median nervure is interstitial. Abdomen smooth, shining, impunctate; the gastrocœli are indicated by a shallow depression.

The scutellum in this species might refer it to *Hoplismenus*, but it differs from that in having no spines on the median segment. The shape of the scutellum is quite similar to what it is in some Mexican species of *Ichneumon*, *e.g. I. aztecus.*

B. Scutellum flat, normal.

ICHNEUMON ACTISTA, *sp. nov.*

Niger, thorace coxisque albo-maculatis; pedibus rufis; alis fere hyalinis, stigmate nervisque nigris, ♂. Long. 14 mm.

Antennæ black; the scape with a yellow mark in the middle on the lower side. Head: the face below the antennæ, the mandibles except the teeth, the palpi, a mark on the vertex touching the eyes, and a larger mark behind lower down, yellow; almost impunctate, the front and vertex thickly covered with short blackish hair, the labrum fringed with longish fulvous hair; behind, it is as long as the eyes and sharply oblique. Thorax oblique in front; the sides of the pronotum widely, a large square mark on the mesonotum in the middle, the scutellum, postscutellum, the supramedian area of the metanotum, two large marks on the mesopleuræ, the anterior slightly the larger, and a large oblique mark on the metapleuræ, yellow. Metanotal areæ well developed; the keels acute, the supramedian rounded at the base; the sides straight, gradually narrowed to the apex, which is transverse; the apex has an oblique slope. The four anterior coxæ are white beneath; the hinder have a large white mark at the base above and beneath; the trochanters are black. The

alar nervures and stigma are deep black; the transverse basal nervure is interstitial; the areolet is narrowed at the top, being there in length less than the space bounded by the recurrent and the second transverse cubital nervures. Abdomen deep black, very smooth, shining; the gastrocœli shallow, smooth, indistinct.

ICHNEUMON HELMSII, *sp. nov.*

Niger, abdomine pedibusque rufis; scutello flavo; alis fulvo-hyalinis, stigmate fulvo. ♂. Long. 15 mm.

Antennæ black; the scape with a yellow mark in the middle beneath; the apical joints dilated on the lower side, the scape thickly covered with longish black hair. Face with clypeus strongly punctured, thickly covered with short white hair; the sides of the clypeus, a broad mark on the cheeks close to the eyes, with its top obliquely truncated and narrow, projecting obliquely from the base of the truncated part into a pear-shaped mark, which extends in the middle beyond the base of the antennae, but not uniting there, the labrum and palpi, yellow; the tips of the mandibles piceous; their basal half strongly punctured. Behind the eyes the head is obliquely narrowed; the hinder part rather deeply and roundly narrowed inwardly and margined; mesonotum and upper part of the pronotum closely and strongly punctured; the lower part of the propleuræ smooth and shining; the prosternum closely punctured. Scutellum entirely yellow, smooth, shining, flat; the postscutellum punctured. Median segment coarsely and irregularly punctured; the supramedian area almost square, but slightly narrowed towards the apex; the base and apex transverse; the apex of the segment with an oblique slope; coarsely, irregularly, transversely striolated and reticulated; its centre deeply furrowed at the base; the keels bordering it distinct, curved; the lateral keels

on the top stout, ending in the middle in a stout, flat, triangular tooth. Meso- and meta-pleuræ strongly punctured, the latter on the lower side with a curved keel. The coxæ and base of the trochanters are black; the hinder coxæ have a reddish mark on the apex behind; the extreme apex of the hinder femora black; the apices of the hinder tibiæ and of the tarsal joints infuscated. The wing nervures to the stigma, and the stigma itself, fulvous, the apical nervures black; the areolet narrowed at the top, being there distinctly less in length than the space bounded by the recurrent and the second transverse cubital nervures. The apex of the petiole closely, longitudinally striated, and marked with yellow at the sides; down the sides from the base is a narrow black line which is continued down the middle to opposite the spiracles, becoming thickened towards the apex; the spiracles are bordered with black; the other segments are closely punctured; the second and third have the sides at the apex yellowish; the gastrocœli deep, wide at the apex, being somewhat triangular seen from the outer side; smooth, shining, the middle at the apex with a few striæ.

This is the largest and stoutest-looking species of the New Zealand species of *Ichneumon*, and is very distinct from any of them.

ICHNEUMON DECEPTUS Sm.

Smith (*Trans. Entom. Soc.*, 1876, p. 477) only describes the ♀ of this species, so I now describe the ♂.

Scape of the antennæ beneath, the face below the antennæ, the mandibles except the teeth, the palpi, a broad line on the outer orbits of the eyes on the lower side, the pronotum broadly, a squarish mark in the centre of the mesonotum, the scutellum, post-scutellum, a square mark on the median segment, a mark on the base of the mesopleuræ, a smaller one at the apex lower down, a

small one on the apex of the propleuræ and a large one at the apex of the metapleuræ, yellow; the four anterior coxæ are yellow as are also the trochanters, the rest of the legs having also a yellowish hue; the hinder coxæ and trochanters are black, the former with a large yellow mark behind. On the abdomen above, the fifth and sixth segments are more or less black. The wings vary in tint.

ICHNEUMON LOTATORIUS Fab.

Ichneumon lotatorius Fab. has been described by Mr. W. F. Kirby (*Trans. Entom. Soc.*, 1883, p. 200) as an aculeate under the name of *Priocnemis Pascoei*. I have examined the type in the British Museum. It agrees with *Ichneumon insidiator* Sm., and differs from the other species in having the petiole black; but *I. insidiator* has the extreme apex of it yellowish, while *I. lotatorius* differs from it in having the apex of the hinder femora and of the hinder tibiæ black; the mesonotum not distinctly punctured, and only the second abdominal segment is red, while in *I. insidiator* the second and third are entirely yellow.

Smith (*Trans. Entom. Soc.*, 1876, p. 476) remarks that his *I. insidiator* is probably the ♂ of *I. lotatorius* Fab., but Mr. Kirby treats it as distinct.

As *I. lotatorius* has not been properly described I give a description of both sexes here.

♂ Black; the scutellum and tubercles yellow; the legs and second abdominal segment reddish-fulvous, the front legs with a more yellowish tinge; the coxæ, anterior trochanters, the base of the posterior, the apex of the hinder femora broadly, and the apex of the hinder tibiæ more narrowly, black; the wings fulvous or more or less deeply smoky; the stigma testaceous.

♀ Antennæ short, thick, involute; pruinose towards the apex, the base with short black hair. Head strongly

punctured, much more closely in the centre below the antennæ; the oral region with the punctures much more widely separated and covered with longish fulvous hair; the palpi testaceous; the eyes margined distinctly. Pronotum closely punctured; the mesonotum with the punctures more widely separated; the scutellum almost impunctate; median segment closely punctured; the areæ all distinctly defined; the supramedian longer than broad; the apex is closely and somewhat coarsely transversely striated. Meso- and meta-pleuræ closely and strongly punctured. Coxæ strongly punctured. Abdomen smooth and shining, impunctate; the gastrocœli impunctate. The areolet at the top narrowed, being there a little less than the space bounded by the recurrent and the second transverse cubital nervures; the recurrent nervure is bent towards the apex of the wing near the middle, and has there a minute branch.

ICHNEUMON INSIDIATOR Sm.

Smith's description, which only relates to coloration, may be supplemented as regards other points.

Comparing it with the ♂ of *I. sollicitorius*, it may be known from it by the petiole being black, only yellow at the apex, whereas in *I. sollicitorius* it is entirely yellow; the face is black in the middle, the thorax above and at the sides is much more strongly punctured, as are also the the coxæ; the thorax is broader in front at the tegulæ; the post-scutellum black; the median segment strongly aciculated; the transverse cubital nervure at the base in the middle, is angled with a short branch issuing backwards from the middle of the angle, whereas in *I. sollicitorius* it is rounded; and the stigma is testaceous, not blackish.

ICHNEUMON SOLLICITORIUS Fab.

Apparently a common species. I have only seen the male.

ICHNEUMON ARTAXIDIA, *sp. nov.*

Capite thoraceque ferrugineis ; scutello flavo, abdomine nigro, basi late rufo-flavo ; pedibus rufo-fulvis, coxis trochanteribusque nigris ; alis cum nervis flavis. ♂. Long. 8 mm.

Scape of antennae dark-rufous, blackish above ; the flagellum absent. Head closely, but not strongly punctured ; covered rather closely with pale hair ; the clypeus with the hair longer and paler, and only with a few scattered punctures ; the labrum fringed with longer hair ; the mandibles strongly punctured ; their teeth black Thorax dark-ferruginous ; the prosternum, a large oblique mark on the propleurae, a large oblique mark on the mesopleurae extending from the base to the apex, a mark on either side of the mesosternum at the apex, the metapleurae except the apex above and the sides of the median segment, black. Mesonotum closely punctured ; the scutellum, post-scutellum and the centre of the median segment at the base, yellow. The pro- and meso-pleurae closely punctured ; the propleurae with a few distinct striae at the apex in the middle ; the top of the mesopleurae at the apex and the metapleurae smooth and shining ; the base of the metapleurae with a wide, deep, crenulated furrow at the base. The median segment has no areae, and the only keel is one bordering the apex above ; the sides at the apex between this keel and the lateral at the apex is irregularly crenulated. Abdomen smooth and shining ; the third and following segments black ; the gastrocoeli indistinct.

ICHNEUMON IXIA, *sp. nov.*

Rufus, abdominis apice late nigro, scutello flavo ; alis hyalinis, stigmate flavo, nervis fuscis. ♀. Long. 7·5 mm.

Antennae stout, involute, bare, obscure-rufous, the

flagellum darker above; the scape with a few punctures on the under side. Head dark-rufous; the front and two large marks on the sides above the clypeus, black; the vertex strongly punctured; the face and clypeus with the punctures much fewer and more widely separated; the face in the middle with a few fine transverse striations; the front largely excavated, smooth and shining. The eyes distinctly margined; the inner orbits narrowly lined with yellow. Mesonotum rufous, a broad black band down the centre and a narrower one down the sides; closely, but not strongly, punctured. Scutellum rufous, the apex broadly yellow; the apex almost impunctate; the remainder bearing clearly separated, moderately large, punctures; the post-scutellum for the greater part yellow. At the base of the scutellum is a wide, deep curved furrow. The median segment has a gradually rounded slope to the apex, which is oblique; it is smooth and shining, almost bare; the supramedian area is large, somewhat wider than long, rounded at the base, the sides straight, oblique; the apex rounded on its inside; the supra-external areæ are finely punctured; the posterior median area is roundly excavated, not much narrowed towards the apex, and finely and closely punctured; the posterior intermedian areæ are not so closely, but much more strongly, punctured; and, at the top, is a yellowish mark; the pro- and meso-pleuræ are strongly punctured, the former obscurely striated at the apex; the mesopleuræ black, except a large rufous mark in the middle at the base and a larger one lower down at the apex; the sternum for the most part black; the metapleuræ very smooth, shining, impunctate, black, except over the coxæ. Legs dark rufous; the anterior brighter in tint; the hinder femora much darker, abdomen smooth and shining, the three basal segments red; the apical black.

ICHNEUMON COLENSII, *sp. nov.*

Rufus; orbitis oculorum, linea pronoti, lineis 2 mesonoti, scutello, post-scutelloque flavis; abdominis apice late nigro; alis fulvo-hyalinis, stigmate flavo. ♀. Long. 7 mm.

Scape of the antennæ dark-ferruginous, finely punctured, thickly covered with short dark hair, the flagellum black, paler on the lower side. Head rufous; the vertex in the centre darker; the inner orbits, broad at the top, narrow at the bottom, a curved line at the top, and the outer side beneath, lemon-yellow; the face and vertex punctured, but not strongly, their sides almost impunctate; the clypeus with a few scattered punctures; the mandibles punctured, suffused with yellow at the base; the apex black; the palpi pale-yellow. Thorax rufous; a broad line on the pronotum, the scutellum, post-scutellum, the lower side of the propleuræ and of the mesopleuræ broadly, two narrow lines on the centre of the mesonotum and the apex of the metapleuræ below, lemon-yellow. The mesonotum is punctured; there is a central and two large lateral black marks, the latter bordered on the inner side by the yellow lines; the apex of the scutellum is rufous, and it has a few shallow punctures. The median segment has an almost gradually rounded slope and is strongly punctured at the sides; the areæ complete, the supramedian longer than broad, rounded at the base; the pro- and meso-pleuræ closely punctured; the propleuræ broadly black in the middle; the mesopleuræ broadly black above and at the apex; the metapleuræ very smooth and shining, impunctate. Legs uniformly rufous; the fore coxæ pale-yellow; there is a lemon-yellow mark over the hinder pair above at the base. Alar nervures dark fuscous, the stigma pale testaceous; the areolet narrowed at the top. Abdomen smooth and shining; the apical three segments black; the gastrocœli indistinct, finely and closely punctured.

ICHNEUMON URSULA, *sp. nov.*

Ferrugineus, thorace nigro-maculato ; orbitis oculorum, linea pronoti, lineis 2 mesonoti scutelloque flavis ; alis fulvis stigmate nervisque fulvis. ♀. Long. 9 mm.

Head : the inner orbits to the hinder edge of the eyes above and a mark, longer than broad, on the outer edge beneath, yellow ; the vertex with shallow, widely separated punctures ; the front shining, impunctate, the middle with a few transverse striations ; the mandibles and palpi pallid-yellow ; the apex of the mandibles black ; the clypeus is very shining, with a few widely separated punctures. Antennæ broken off. Thorax : the edge of the pronotum, a line on the lower edge of the propleuræ, two lines in the middle of the mesonotum, the scutellum, post-scutellum, a mark over, and in front of, the middle and a smaller one over the hinder coxæ, lemon-yellow ; a mark at the base of the mesonotum in the centre, its apex being triangular, two broad lines down its sides outside the yellow ones and the scutellum and post-scutellum, lemon-yellow. The scutellum is broader than long, smooth, impunctate, the depression at its base black. The median segment strongly shagreened, more strongly on the sides at the apex ; the areæ complete ; the supramedian bluntly rounded at the base, the sides straight, a little narrowed towards the apex ; the posterior median of nearly equal width, not much hollowed in the centre, its apex with a few transverse striæ, the middle almost smooth, hardly shagreened. In the centre of the propleuræ is a large, somewhat triangular mark ; the mesopleuræ under the wings broadly, the mesosternum and the basal three-fourths of the metapleuræ, black. Legs uniformly ferruginous. Wings hyaline, but with a decided fulvous tinge ; the stigma narrowed at the top, being there narrower than the space bounded by the

recurrent and the second transverse cubital nervures; the latter is received shortly beyond the middle of the areolet. Abdomen smooth, shining, impunctate; the fifth and sixth segments broadly black; the gastrocœli shallow, not very distinct, finely aciculated. The ventral segments are pallid-yellow in the middle.

ICHNEUMON BROUNI, *sp. nov.*

Long. 7 mm. ♂.

A very similar species to *I. falsus*, but is smaller; the sternum is black; the hinder coxæ are without any black; the petiole is smooth, not shagreened; the gastrocœli are deeper and more clearly defined; and the recurrent nervure is broadly curved, while in *I. falsus* it is slightly angled in the middle and emits there a short branch.

Antennæ black, the scape yellow beneath; the apical joints of the flagellum dilated on lower side. Head pale-yellow; the occiput, and the vertex and front broadly in the centre, black; the tips of the mandibles black; the face sparsely pilose; the clypeus with longish pale, the vertex thickly covered with black hair; shagreened; the hollowed front smooth and shining. Thorax black; a broad line of equal width on the pronotum, two lines on the mesonotum, scutellum, post-scutellum, the median segment, the lower edge of the pronotum, a short line opposite the tegulæ, the scutellar keels at the base, the scutellum, post-scutellum, two large marks on the apex of the median segment, the tubercles, the lower half of the mesopleuræ, and a line on the lower side of the propleuræ, lemon-yellow. The mesonotum has the punctures somewhat close together, those on the scutellum are larger and more widely separated; the median segment has only a few minute punctures at the base. The propleuræ have the punctures shallow and widely

separated: the mesopleurae are more strongly and closely punctured, except the usual smooth spot on the apex; the metapleurae smooth, impunctate. The base of the median segment, the supra and the posterior median areae are blood-coloured: the supramedian is not much wider than long. The median segment has a gradually rounded slope; at the base of the median segment below the wings is a yellow and rufous spot. The areolet is triangular at the top, the nervures being almost united there. The four anterior coxae, trochanters and lower side of the femora are lemon-yellow; the rest fulvous: the hinder legs dark rufous, the tarsi paler; the hinder coxae black above, and to near the middle, the rest of the sides and their lower side fulvous; at their base is a large, somewhat triangular lemon-yellow mark. The petiole is, towards the apex, roughly irregularly shagreened: the other segments are closely punctured; the gastrocoeli shallow, at the base closely longitudinally striated.

ICHNEUMON FALSUS, *sp. nov.*

Niger; ore, sterno, linea pronoti, scutello, lineis 2 mesonoti metanotoque flavis; abdomine ferrugineo, apice late nigro; pedibus anterioribus rufis, coxis trochanteribus que flavis, pedibus posticis fusco-ferrugineis; alis fere hyalinis, stigmate nigro. ♂. Long. 10 mm.

Antennae black, slightly brownish beneath; the scape lemon-yellow on the under side. The face from below the antennae, including the oral region, the mandibles and the palpi, the inner orbits narrowly to shortly below the ocelli, and the lower orbits—broadly beneath, narrowly above—lemon-yellow. The face strongly punctured, the clypeus with a few scattered punctures; the frontal depression deep, shining, the edges aciculated. The line on the pronotum is broad and dilated at the

base; the two lines on the pronotum are also dilated at the base and extend to near the scutellum; a mark on the lower half of the mesopleurae and the sternum, lemon-yellow. The propleurae impunctate; the upper parts of the mesopleurae at the base strongly punctured, the apical impunctate in the middle, and the metapleurae impunctate. The base of the median segment reddish (perhaps through discoloration): the supramedian area a little broader than long, rounded at the base; the posterior median complete; the others obsolete. The alar stigma and nervures black; the areolet at the top a little less in width than the space bounded by the recurrent and the second transverse cubital nervures. Legs fulvous; the four anterior coxae and trochanters lemon-yellow; the hinder coxae fulvous like the femora and yellow at the base above and in the middle, the rest of them black. Abdomen reddish; the apical three segments black above; the base of the second segments shagreened; the gastrocœli moderately wide, deep.

ICHNEUMON LEODACUS, *sp. nov.*

Ferrugineus, scutello flavo; metapleuris, coxis trochanteribusque posticis nigris, alis flavis. ♂. Long. 8 mm.

Scape of antennæ rufous, punctured, thickly covered with pale hair; the flagellum fuscous. Head: the face strongly punctured; the clypeus shining, impunctate; the face covered closely with short white hair; the clypeus has the hair longer, sparser and darker in colour; the vertex and occiput more closely punctured than the face; the tips of mandibles black; the palpi pale-testaceous; the inner and outer orbits above reddish-yellow. Mesonotum shining, the sides finely and closely punctured, the middle almost impunctate. Scutellum and post-scutellum shining, impunctate, orange-yellow. The base of the

median segment rounded, the rest of it sharply oblique ; the sides at the base shagreened ; the apex in the middle transversely striated ; the rest coarsely shagreened. There are no areæ, and only a stout curved keel over the oblique keel. The propleuræ impunctate ; in the centre is a large somewhat triangular black mark ; the mesopleuræ slightly punctured ; in the centre at the apex is a black mark, narrowed towards the apex ; immediately in front of the middle coxæ is a larger, somewhat similarly shaped, black mark ; the metapleuræ smooth, impunctate, black, except an elongate mark at the top, and a shorter, broader and more irregularly-shaped one over the coxæ. The legs are uniformly coloured, except the hind coxæ and the basal joint of the hinder trochanters, which are black. The areolet is narrowed at the top, being there a little less than the space bounded by the transverse cubital and the recurrent nervures, the latter being received almost in the centre of the cellule. Abdomen smooth, shining, impunctate ; the gastrocœli indistinct, closely punctured.

ICHNEUMON MACHIMIA, *sp. nov.*

Niger, orbitis oculorum, linea pronoti, tegulisque scutelli flavis ; abdomine rufo ; pedibus anticis rufis ; tibiis tarsisque posterioribus sordide rufis ; alis fusco-hyalinis, stigmate rufo-testaceo. ♀. Long. 8 mm.

Front strongly punctured ; the clypeus shining and bearing a few scattered punctures ; the vertex shagreened, the ocellar region rough, the inner orbits and round the top to opposite the tegulæ, as well as a line at the foot, yellow ; the clypeus and labrum rufous (perhaps a discoloured yellow) ; the mandibles a dirty yellow, the teeth black ; the palpi yellow ; the face and clypeus have a few white hairs. Antennæ black, the scape shining, and bearing a few punctures. Thorax shining, the mesonotum impunctate ; the median segment coarsely aciculated

The edge of the pronotum, tegulæ, two longitudinal lines on the mesonotum, the scutellum and post-scutellum, yellow. Median segment thickly covered with longish pale hair, coarsely aciculated, the areæ distinct except the posterior median, the keels of which are obliterated. The propleuræ, except at the base, closely obliquely striated, the striæ coarser on the lower side, the mesopleuræ rather strongly and distinctly punctured, the base of the median segment punctured, the rest longitudinally shagreened, running into striations on the lower side. All the coxæ and trochanters are black; the fore femora, tibiæ and tarsi rufous, as are also the four posterior, but these are darker in tint, this being especially the case with the femora. Abdomen shining; the apex of petiole closely punctured, the gastrocœli shallow, indistinct; the sheaths of the ovipositor black.

Has the look and form of a *Cryptus*, but is a true *Ichneumon*.

ICHNEUMON UTETES, *sp. nov.*

Rufus, pleuris nigris; femoribus posticis fuscis; alis hyalinis, stigmate flavo, nervis fuscis. ♀. Long. 5 mm.

Antennæ short, stout, almost bare, if anything thickened beyond the middle, uniformly rufous. Head rufous, the vertex darker, the excavated front black; the face strongly punctured; the clypeus with only a few shallow punctures; the front transversely striated in the middle; the vertex and occiput closely and rather strongly punctured; the outer orbits, except at the top, very smooth, and shining, and with only a few shallow scattered punctures; the mandibles rufous, their teeth black; the palpi testaceous. Thorax rufous; the mesonotum in front infuscated; the propleuræ black, except above and beneath; the base indistinctly striated; the mesopleuræ black, except a pale testaceous mark on the apex above

the middle coxæ, the extreme base being rufous; closely punctured; the apex over the coxæ indistinctly and irregularly striolated; the metapleuræ above very smooth and shining; the lower part finely longitudinally striolated. The scutellum is, if anything, more strongly punctured than the mesonotum. The median segment has the areæ complete; the supramedian area is transverse at the apex; the top obliquely narrowed, the middle itself being transverse; the apex of the segment has an oblique slope; the middle is slightly hollowed, closely punctured; the top almost smooth, the bottom obscurely transversely striated; the posterior median area with straight sides; the legs rufous; the base of the middle coxæ and the hinder coxæ above, black; the latter strongly punctured. Abdomen rufo-ferruginous, smooth and shining, glabrous except for a few hairs on the apex and sides; the sides of the 2-5 segments blackish. The alar areolet narrowed at the top, being there in width very little less than the space bounded by the second transverse cubital and the recurrent nervures.

ICHNEUMON THYELLMA, *sp. nov.*

Long. 5·5 mm.

Comes near to *I. utetes*, with which it has a close resemblance in coloration, but differs in having the areæ on the median segment and the nervures all distinctly developed.

Scape of the antennæ black above, yellowish beneath. Head pallid-yellow, suffused with testaceous above; the occiput, the vertex and front broadly in the middle, black; the vertex strongly and closely punctured; the face not quite so strongly; the front finely punctured in the middle, the sides very smooth and shining; the mandibles and palpi pallid-yellow; the tips of the mandibles piceous. Prothorax black, edged above and beneath with

pallid-yellow, shining, impunctate. Mesonotum finely punctured, its centre broadly rufo-testaceous, darker in the middle, the sides black; the scutellum probably testaceous, but the pin goes through it. Median segment with a rounded slope; its base black; the areæ all distinctly defined; the supramedian slightly narrowed towards the base; truncated at base and apex; the posterior median area obscurely transversely striated. Except at the top behind the mesopleuræ, closely punctured; the upper part to the middle, black; immediately below the black part, rufous, followed by a pale-yellow band; the sternum rufous. Metapleuræ black, with a broad rufous mark in the middle on the apical three-fourths, the rufous turning into clear pale-yellow at the apex. Wings hyaline, the stigma and nervures fuscous. Areolet at the top nearly the length of the space bounded by the recurrent and the second transverse cubital nervures; the recurrent nervure received shortly beyond the middle. Legs fulvous; the four anterior coxæ for the greater part pallid-yellow. Abdomen rufous, closely punctured; the basal three-fourths of the petiole black; its apex closely punctured. Gastrocœli shallow, indistinct, closely punctured.

ICHNEUMON NOVA-ZEALANDICUS, *sp. nov.*

Niger, pedibus abdomineque rufis, capite thoraceque rufo- et flavo-variegatis; alis hyalinis, nervis stigmateque flavo-testaceis. ♀. Long. fere 5 mm.

Scape of antennæ rufous, black above, the flagellum absent. Head rufous, the orbits on the inner side and above and beneath on the outer side, as well as the base of the mandibles, yellow; the front deeply excavated, black; the vertex blackish, broadly so in the centre; the face minutely punctured, the vertex aciculated. The mesonotum minutely punctured; down the centre are two

rather broad rufo-testaceous lines, the scutellum and post-scutellum are yellow, suffused with rufous. Median segment sharply oblique, the middle slightly hollowed; the sides broadly rufo-testaceous; there are no keels except the curved lateral ones, and on the apex the testaceous part is bordered on the inner side by a lateral keel. The propleuræ above and beneath bordered with yellow; obscurely striolated; the mesopleuræ black above, bordered with rufous; the middle broadly yellow, the sternum rufous; the base above finely longitudinally striated, the rest punctured; the metapleuræ smooth, shining; a short, wide, deep, oblique furrow at the base above. The coxæ and trochanters are rufous, suffused with yellow. Areolet narrowed at the top, being there not much less in width than the space bounded by the recurrent and the second transverse cubital nervures. Abdomen uniformly ferruginous, shining; the basal three-fourths of the petiole black above; the sheaths of the ovipositor rufous, black at the apex; the ventral surface tinged with yellow.

Comes nearest to *I. utetes*, but that species has the pleuræ and sternum blackish and the mesopleuræ strongly striolated.

DICOELOTUS STRIATIFRONS, *sp. nov.*

Rufus, antennis nigris; orbitis oculorum, tegulis, linea pronoti, lineis 2 mesonoti scutelloque flavis; metapleuris striolatis; alis hyalinis, stigmate testaceo. ♀. Long. 6 mm.

Antennæ black; the scape and the basal half of the flagellum brownish beneath; the flagellum almost bare, the scape with a few hairs on the under side. Head shining, the face and clypeus with longish pale hairs; the vertex punctured, except at the sides; the antennal depression closely transversely striated; the front with a

shallow longitudinal furrow over the depression; the clypeus obliquely depressed in the middle at the centre, the depression almost semicircular; the top with a few punctures; the centre below the antennæ broadly, roundly and distinctly raised; the mandibles rufo-testaceous; the tips black; the palpi pale-testaceous. The frontal depression black; the vertex blackish at the ocelli; the inner orbits narrowly at the bottom, broadly at the top, and narrowly again behind the eyes, yellow. Prothorax in front, the edge of the pronotum, two lines in the centre of the mesonotum, the scutellum except at the apex, the propleuræ and the mesopleuræ over the coxæ, lemon-yellow; the propleuræ almost entirely black, as is also the sternum; the upper half of the mesopleuræ, and the metapleuræ, black; the mesopleuræ strongly punctured, except the usual smooth space behind; the base above almost longitudinally striated; the metapleuræ very finely and closely longitudinally striated; a red and yellow mark over the coxæ. Scutellum flat, large, not much narrowed towards the apex, the post-scutellum rufous, very smooth, and having two large, deep, oval depressions at the base. Median segment shagreened, almost striated in the middle; the supra-median area longer than broad; bluntly rounded at the base. The four anterior coxæ coloured like the femora; the hinder broadly black at the base beneath, and with a yellow mark at the base behind. Abdomen shining, the apex of the fourth, the fifth and the sixth, black. In the fore wings the transverse median nervure is interstitial; the areolet is much narrowed at the top, being there less in length than the space bounded by the recurrent and the second transverse cubital nervures.

Appears to be a true *Dicælotus*, the first species of the genus recorded, I believe, out of Europe. The foveæ at the base of the post-scutellum are large and deep, more so, in fact, than in most species of the genus.

CRYPTINA.

MESOSTENUS ALBO-PICTUS Sm.

Smith, *Trans. Entom. Soc.*, 1876, p. 477, pl. IV. f. 1.

One ♀. A large and handsome species.

HEMITELES DESTRUCTIVUS, *sp. nov.*

Niger, pedibus abdomineque rufo-testaceis, petiolo nigro; alis hyalinis, stigmate fusco. ♀. Long. 5 mm.; terebra 1 mm.

Head absent. Thorax entirely black, shining; the pro- and meso-thorax thickly covered with short pale hair, almost impunctate, the lower part of the pro- and meso-pleuræ strongly longitudinally striated, except the usual impunctate spot on the apex of the latter; the part of the metapleuræ below the keel obliquely striated, that above it rugose. The median segment rugosely punctured; the areæ all distinctly defined; the sides with a distinct tooth near the top of the apical part Legs rufo-testaceous; the trochanters paler; the hinder coxæ black, except at the apex. Wings clear hyaline, the stigma and the nervures paler; the recurrent nervure is received in the apical third of the cellule, the tegulæ pallid-testaceous. Petiole black, finely and closely longitudinally striated; apical segments of abdomen thickly covered with short pale hair.

PIMPLIDES.

RHYSSA SEMIPUNCTATA.

The species described by Mr. Kirby (*Trans. Entom. Soc.*, 1883, p. 202) cannot be referred to *Rhyssa*. I am not quite certain to which genus it belongs; assuredly not to *Rhyssa*, which *inter alia* differs in having the mesonotum transversely striolated.

Compared with *Pimpla* the face is longer, the eyes

being separated from the base of the mandibles; the clypeus is much larger, more elongate and narrowed gradually towards the apex; the mandibles have two teeth at the apex; the eyes are distinctly margined on the inner side; the centre of the mesonotum at the base is separated by deep crenulated furrows into a cone-shaped lobe, the sides of the pronotum being raised at the base of the furrows, which are produced as one a short distance beyond the apex of the lobe; the scutellum is narrowed towards the apex, curved at the base; the keels are large and acute. The median segment is strongly and uniformly transversely striated; the centre flatly raised; the sides stoutly keeled; the keels ending in a stout blunt tooth; the apex with an oblique slope and with the sides keeled. The top and base of the mesopleuræ are depressed; the edges of the depression crenulated; in the middle and reaching near to the apex is a wide, deep, slightly oblique furrow; the hinder edge has a wide, flat, slightly oblique, crenulated furrow; and, in front of this on the lower side, is a short, wide, oblique depression. The legs are stout; the hinder femora have, shortly beyond the middle, a short, somewhat triangular tooth; the tibiæ are spined, especially the hinder, the middle pair having only a few and the anterior none at all; the tarsi are spined; the claws long, curved, simple. The abdomen smooth, shining and impunctate throughout; the base oblique, not hollowed; the sides of the second and third obliquely furrowed, the furrows being more distinctly defined than in *Pimpla*. The fore tarsi are twice the length of the tibiæ; the middle segments of the abdomen broader than long; the ovipositor issues from a ventral cleft.

The ♂ offers no noteworthy generic character wherein it differs from the ♀.

The toothed posterior femora, spined tibiæ, elongated face, deeply lobed mesonotum, furrowed mesopleuræ

and median segment form a combination of distinctive characters which warrants a new genus being formed for this species, which I would name *Xenopimpla.*

The ♂ is not described by Kirby. It agrees generally in coloration with the ♀; but the scutellar keels, the apex of the scutellum, the post-scutellum, the edges of the apex of the mesonotum, and the metanotal spines are yellow; the furrow on the mesopleuræ and the apex of the mesopleuræ, are black, but the extreme apex of the latter is yellow; the petiole is bordered with yellow, the yellow band being narrowed in the middle; the yellow marks on the abdomen extend to the fifth segment; one, two, or three of the apical segments may be red; the hinder tibiæ may be for the greater part blackish and they are less strongly spined. In both sexes the quantity of black on the antennæ varies, as does also the amount of violaceous colour in the wings.

LISSONOTA TINCTIPENNIS, *sp. nov.*

Rufa; antennis nigris; thorace albo-maculato; alis fere flavo-hyalinis. ♀. Long. 10 mm.

Antennæ entirely black, covered with a microscopic down; the scape slightly black-haired. Head shining, the vertex closely punctured, almost glabrous; the face sparsely covered with short white hair; the orbits all round, but more narrowly at the top, and the mandibles, white; the mandibular teeth blackish; the mandibles at their base piceous; the palpi pale-rufous. Thorax dark-rufous; the middle of the mesonotum broadly, the sides less distinctly, the lower part of the propleuræ, the sides and top of the mesopleuræ, the hinder part of the mesosternum and the edges of the metathorax, black; the base of the pronotum, a somewhat triangular large mark on either side of the mesonotum at the base, two elongate

marks, dilated at the middle, at its apex, the scutellum, the post-scutellum, a large somewhat oval mark at the base of the mesopleuræ, and a large oblique one on the metapleuræ, white. The median segment transversely aciculated, less strongly so at the base; before the apex is a stout transverse curved keel; and in the centre are a few transverse striæ. Legs entirely rufous; the fore pair slightly paler in tint. Abdomen smooth, shining, impunctate. Wings hyaline, iridescent, and with a slight fuscous tinge; the stigma and nervures fuscous; the areolet oblique.

Allied to *L. flavo-picta* Sm., but that has only two yellow marks on the mesonotum, no yellow on the metapleuræ, and the coxæ are yellow. *L. albo-picta* Sm., has the head black.

TRYPHONIDES.

CHORINÆUS (?) FORTIPES, *sp. nov.*

Long: 5 mm. ♀.

The specimen of this species unfortunately wants the head, but it differs so much from *C. nigripes* that there can be no doubt of their distinctness. It differs from *C. nigripes* in the petiole having two strong keels down its centre, which is, further, much more distinctly raised and separated from the sides.

Pro- and meso-notum shining, closely and strongly punctured, thickly covered with black hair; the scutellum with large distinctly separated punctures. Median segment depressed and distinctly margined at the base, rough, indistinctly punctured, thickly covered with greyish hair; the two keels in the centre much stronger than they are in *C. nigripes*, and are continued round the sides of the apex. All the pleuræ smooth and shining, sparsely haired; the sternum thickly covered with fuscous hair. Wings fusco-hyaline; the stigma and nervures dark-

fuscous; the transverse cubital nervures united at the top; the recurrent nervure is received in the apical third of the cellule. Legs black, thickly covered with longish white hair; the base and apex of the anterior tibiæ and the fore tarsi for the greater part testaceous. Abdomen strongly punctured, thickly covered with short pale hair; the petiole strongly keeled down the centre to shortly beyond the middle; the base not much depressed in the centre.

The two species I have here referred to *Chorinæus* agree better with that genus than with any other. The keels on the second and third abdominal segments characteristic of *Chorinæus* can hardly be said to exist; the femora and the legs generally are stouter than they are in *e.g.* the European *C. funebris;* while both species differ in the areolet being complete.

CHORINÆUS NIGRIPES, *sp. nov.*

Niger, tibiis tarsisque anticis testaceis; alis fere hyalinis. ♀.

Long. fere 6 mm.

Face at the sides finely and closely transversely striated, in the centre irregularly rugose; covered with long, soft white hair; the front and vertex shining, impunctate; more thickly covered with shorter hair than on the face; the palpi dark-testaceous. Thorax shining, impunctate; the pro- and meso-notum thickly covered with short dark hair; the median segment coarsely shagreened, except in the middle at the apex where it is shining and impunctate; down the centre are two distinct keels which slightly diverge at the apex. Pleuræ shining, impunctate; the metapleuræ on the lower side bordered by a stout keel. Legs black; the front knees, tibiæ and tarsi, testaceous; the four hinder tarsi of a darker testaceous colour, the metatarsus being almost fuscous. Wings hyaline, very slightly infuscated; the stigma almost black;

the nervures testaceous ; the areolet narrow, longish ; the recurrent nervures united at the top ; the first transverse cubital nervure thick, the second narrow, faint on lower side ; the recurrent nervure received near the apex of the areolet and largely bullated at the top ; the first transverse cubital nervure bulges out backwards, forming a triangle. The basal three segments of the abdomen strongly punctured, the others impunctate, thickly covered with longish pale hair.

BASSUS GENEROSUS, *sp. nov.*

Niger, orbitis oculorum, ore, palpis, linea pronoti, scutello, tegulis, lineaque tibiarum posticarum albis ; pedibus rufis ; tarsis posticis nigris ; alis hyalinis, stigmate fusco. ♀.

Long. 6 mm.

Head black ; the face punctured, sparsely covered with short fuscous hair ; the mouth, the base of the mandibles, palpi and inner orbits, white ; the mandibular teeth piceous and black. Thorax black ; a large broad mark on the side of the mesonotum at the base, reaching to the tegulæ, the tegulæ, tubercles, a triangular mark on the pleuræ below the base of the hind wings, the greater part of the scutellum and the post-scutellum, yellowish-white. Median segment closely punctured ; the keels stout ; the supramedian area wider than long ; the large median area rounded on each side at the top ; stoutly transversely striolated. Propleuræ distinctly punctured ; the mesopleuræ almost impunctate, especially in the middle behind ; the metapleuræ minutely punctured. Legs red ; the fore coxæ and the middle at the base, black ; the apices of the coxæ and the trochanters yellow ; the base of the hinder tibiæ broadly black ; a broad white band towards the middle ; at the apex of the white band they are black, the apex itself being rufous. The stigma is for the greater part black ; the base broadly testaceous.

Abdomen black; the apical half of the second and the basal half of the third rufo-testaceous; the apex of the second segment yellow; down the centre of the petiole (but not reaching the apex) are two keels; the extreme apex smooth, but, in front of this smooth part, there are short, stout, longitudinal keels; the second segment has, shortly beyond the middle, a wide, deep, transverse furrow, which is finely longitudinally striolated, and, in the middle, is bent a little backwards; the base of the segment is coarsely but closely punctured; the third segment has also a transverse furrow.

MESOLEPTUS SYBARITA, *sp. nov.*

Niger, capite thoraceque albo-maculatis, apice metanoti, abdomine pedibusque rufis; alis hyalinis, stigmate fusco. ♂.

Long. 9 mm.

Antennæ black; the scape reddish in the middle beneath. Head lemon-yellow; the occiput except at the sides, the vertex except at the orbits, and a broad line down the face to the base of the clypeus, black; finely punctured, very sparsely covered with short pale hair; the mandibles lemon-yellow, black at the apex; the palpi yellow, without a lemon tint. Thorax black; a broad line on the pronotum not reaching to the base, two lines in the centre of the mesonotum extending from the base to the apex, the base of the lines dilated outwardly, club-shaped and touching the pronotum, the scutellum except at the apex, post-scutellum, the prosternum, a large oblique mark on the mesopleuræ, the apex of the propleuræ to near the bottom, the tubercles, a large oblique mark on the apex of the metapleuræ and a small one at the base above, lemon-yellow; the middle lobes of the mesonotum and the apical half of the metanotum brownish-red: above the yellow mark on the mesopleuræ is a large brownish-red mark; the upper part of the

yellow mark being bordered by the same colour; the reddish apex of the metanotum transversely striated. Legs fulvous, the four anterior coxæ, the trochanters and the upper part of the hinder coxæ, lemon-yellow. Areolet triangular; the nervures blackish, the costa dark-testaceous. Abdomen fulvous-red above; the ventral surface, except at the apex, lemon-yellow.

MESOLEPTUS COMPARATUS, *sp. nov.*

Long. 9-10 mm.

Differs from *M. sybarita* in the thorax being almost entirely brownish-red, in the pleuræ having no yellow marks, in the mesonotum having only two small yellow marks, and in the face being broadly black in the middle.

Head black; the orbits of the eyes except for a small space below the top on the outer side, the clypeus, base of mandibles, palpi, two short lines on the apex of the mesonotum, the scutellum, post-scutellum, the prothorax broadly beneath, a small obscure mark on the mesopleuræ in the centre, and a large oblique mark in the centre of the metapleuræ, yellow; the middle lobe of the pronotum, the parts at the sides of the scutella, the base of the median segment broadly in the middle, the mark being narrowed towards the apex, the middle of the propleuræ, the top and base of the mesopleuræ broadly, the mesonotum in the middle behind, the edges of the metapleuræ at the base and beneath, black. The puncturing on the mesothorax is not very strong; the sides of the scutellum obscurely longitudinally striated. Legs reddish, except a large black mark on the hinder coxæ beneath. Areolet oblique, irregular; the transverse cubital nervures not united at the top. Petiole closely and strongly aciculated except at the apex; the second segment aciculated, the others smooth; the three apical broadly blackish.

OPHIONIDES.

Ophion fuscatus, sp. nov.

Long. 11 mm.

Head rufous, the inner orbits bright lemon-yellow, the colour becoming paler as it unites with the rufous colour of the rest of the head; the face coarsely and closely punctured, the clypeus at the base sparsely punctured, its apex almost impunctate; thickly covered with short pale hair; the mandibles pale lemon-yellow, the teeth black; the hinder orbits obscure-yellow; the palpi pale-yellow. The two basal joints of the antennæ are rufous. Thorax rufous, shining; the pro- and meso-notum closely and rather strongly punctured, closely covered with a microscopic pile; the scutellum is not so darkly coloured as the mesonotum, and has the punctures more widely punctured. Median segment finely closely rugose, thickly covered with short fuscous hair. Propleuræ closely and somewhat strongly punctured, thickly covered with short fuscous hair; the base raised and paler in colour. The mesopleuræ strongly punctured; the metapleuræ with the punctures more widely separated, and smaller at base; at the base is a smooth, curved, and in front of the spiracles is a wider, deeper, oblique, furrow, which becomes wider towards the apex, and clearly separating the pleuræ into two unequal parts. Wings hyaline, with a fuscous tinge, the nervures and stigma dark-fuscous. Tegulæ lemon-yellow. Abdomen not quite so dark-luteous as the thorax; the petiole with an elongated depression extending from the front of the spiracles to a slightly greater distance behind them, in the centre on the top; its apex being slightly wider than the base; the ventral surface of the second and third segments pallid lemon-yellow. The genital armature coloured like the abdomen.

The only New Zealand species of *Ophion* with

punctured thorax is *Ophion inutilis* Sm., No. 2. *Trans. Entom. Soc.*, 1878, p. 2, but that appears to be a quite different form, *O. inutilis*, No. 2, having the nervures and stigma ferruginous, while in our species the stigma is black, without a tint of reddish colour; no mention being made of any yellow colour in the eyes in *O. inutilis*. I write "*O. inutilis*, No. 2," for Smith actually described in the *Trans. Entom. Soc.*, 1876, p. 478, another *O. inutilis*, which is treated as identical with the 1878 specimen by Kirby (*Trans. Entom. Soc.*, 1881, p. 45). The 1876 specimen has also no yellow on the head, nor is there any mention of the thorax being punctured, as it is said to be in No. 2.

PANISCUS EPHIPPIATUS Sm.

Apparently a common species, if I have correctly identified our species with Smith's, whose description is not clear. He says, "mesothorax black," which would mean the entire mesothorax; but lower down he says, "sternum black," words which are unnecessary if the whole mesothorax is black. In the Greymouth example only the mesonotum and mesosternum are black; the orbits are obscure yellow; the stigma and nervures dark fuscous. The face is closely, the clypeus more widely, punctured; the tips of the mandibles black; the ocellar region deep-black; the outer ocelli bordered by a distinct furrow on the outer side. The black on the mesonotum does not extend to the sides, nor to the edge of the central lobe. The basal half of the propleuræ obliquely striated; the upper half of the mesopleuræ closely punctured; the centre at the base rough; the lower part punctured; the metapleuræ closely punctured above, the lower part irregularly longitudinally striated; the scutellum closely punctured, the sides sharply keeled. The median segment coarsely and closely transversely striolated, more strongly

towards the apex. Wings hyaline, the nervures and stigma dark-fuscous.

PANISCUS FOVEATUS, *sp. nov.*

Long. 17-18 mm.

A larger species than *P. ephippiatus;* may be known from it by the absence of black on the vertex and thorax, and by the form of the post-scutellum, which is much more convex, has the sides distinctly keeled, and is deeply depressed at the base, the depression being almost bifurcate, through the centre being raised.

The flagellum of the antennæ infuscated; the face and clypeus pallid-yellow; the face more closely punctured than the clypeus; the tips of the mandibles black. Mesonotum shagreened; the scutellum closely punctured, much narrowed towards the apex; the post-scutellum rugosely punctured, the sides at the base (bordering the depression) sharply keeled. Median segment coarsely transversely striated, at its base in the centre is a wide, curved, deep furrow as in *P. ephippiatus.* The propleuræ obscurely obliquely striated; the apex closely punctured; the mesopleuræ closely, but not strongly, punctured; the metapleuræ behind the spiracles finely punctured, the rest much more coarsely punctured, on the lower side almost longitudinally striolated, the lower part of the mesopleuræ is not depressed as it is in *P. ephippiatus.* Wings hyaline, the nervures blackish, the stigma fuscous. The abdomen is uniformly luteous, the apex not being darkened; the sides of the petiole at the base widely excavated.

LIMNERIA ZEALANDICA, *sp. nov.*

Nigra, abdomine rufo, basi late nigro; pedibus rufis, coxis posticis nigris, trochanteribus flavis; alis hyalinis, stigmate testaceo. ♀.

Long. 7; terebra 2.5 mm.

Antennæ nearly as long as the body, black; the scape testaceous beneath; the flagellum thickly covered with short black hair. Head black; the mandibles yellow; their teeth piceous-black; below the antennæ thickly covered with silvery hair; the vertex more thickly with shorter black hair. Thorax black, hardly shining, except on the apex of the meso- and the base of the meta-pleuræ; the propleuræ at the apex longitudinally striolated. The median segment with a curved keel near the base; on the metapleuræ a keel unites to the spiracle, and, from near the apex of this keel, a less distinct one runs to opposite the middle of the coxæ. Legs rufous; the hind coxæ black; the four anterior trochanters pale-yellow; the posterior tarsi infuscated. Petiole black, except the apex, which is very shining and testaceous, at the sides finely striated; the rest aciculated; the second segment black; the apex broadly, the sides narrowly, rufous. The areolet oblique, narrow, the nervures touching at the top; the areolet projecting beneath; the recurrent nervure received beyond the middle of it.

BRACONIDÆ.

ASCOGASTER CRENULATUS, *sp. nov.*

Niger, tarsis fuscis; *alis fumatis*. ♀. Long. fere 5 mm.

Head almost opaque, except the vertex, which is smooth and shining in the centre, covered, especially in front, with a white pubescence; the mandibles pale-yellow at the apex; the teeth piceous; it is closely punctured, the vertex and front being less strongly punctured than the lower parts. Thorax covered with a microscopic white pile; the pronotum irregularly longitudinally striolated in front; the striations in the hollowed middle being the larger. Mesonotum finely and closely punctured; down the middle are two shallow, striated furrows. Scutellum

CRYPTINA.

MESOSTENUS ALBO-PICTUS Sm.

Smith, *Trans. Entom. Soc.*, 1876, p. 477, pl. IV. f. 1.

One ♀. A large and handsome species.

HEMITELES DESTRUCTIVUS, *sp. nov.*

Niger, pedibus abdomineque rufo-testaceis, petiolo nigro; alis hyalinis, stigmate fusco. ♀. Long. 5 mm.; terebra 1 mm.

Head absent. Thorax entirely black, shining; the pro- and meso-thorax thickly covered with short pale hair, almost impunctate, the lower part of the pro- and meso-pleuræ strongly longitudinally striated, except the usual impunctate spot on the apex of the latter; the part of the metapleuræ below the keel obliquely striated, that above it rugose. The median segment rugosely punctured; the areæ all distinctly defined; the sides with a distinct tooth near the top of the apical part Legs rufo-testaceous; the trochanters paler; the hinder coxæ black, except at the apex. Wings clear hyaline, the stigma and the nervures paler; the recurrent nervure is received in the apical third of the cellule, the tegulæ pallid-testaceous. Petiole black, finely and closely longitudinally striated; apical segments of abdomen thickly covered with short pale hair.

PIMPLIDES.

RHYSSA SEMIPUNCTATA.

The species described by Mr. Kirby (*Trans. Entom. Soc.*, 1883, p. 202) cannot be referred to *Rhyssa*. I am not quite certain to which genus it belongs; assuredly not to *Rhyssa*, which *inter alia* differs in having the mesonotum transversely striolated.

Compared with *Pimpla* the face is longer, the eyes

being separated from the base of the mandibles; the clypeus is much larger, more elongate and narrowed gradually towards the apex; the mandibles have two teeth at the apex; the eyes are distinctly margined on the inner side; the centre of the mesonotum at the base is separated by deep crenulated furrows into a cone-shaped lobe, the sides of the pronotum being raised at the base of the furrows, which are produced as one a short distance beyond the apex of the lobe; the scutellum is narrowed towards the apex, curved at the base; the keels are large and acute. The median segment is strongly and uniformly transversely striated; the centre flatly raised; the sides stoutly keeled; the keels ending in a stout blunt tooth; the apex with an oblique slope and with the sides keeled. The top and base of the mesopleuræ are depressed; the edges of the depression crenulated; in the middle and reaching near to the apex is a wide, deep, slightly oblique furrow; the hinder edge has a wide, flat, slightly oblique, crenulated furrow; and, in front of this on the lower side, is a short, wide, oblique depression. The legs are stout; the hinder femora have, shortly beyond the middle, a short, somewhat triangular tooth; the tibiæ are spined, especially the hinder, the middle pair having only a few and the anterior none at all; the tarsi are spined; the claws long, curved, simple. The abdomen smooth, shining and impunctate throughout; the base oblique, not hollowed; the sides of the second and third obliquely furrowed, the furrows being more distinctly defined than in *Pimpla*. The fore tarsi are twice the length of the tibiæ; the middle segments of the abdomen broader than long; the ovipositor issues from a ventral cleft.

The ♂ offers no noteworthy generic character wherein it differs from the ♀.

The toothed posterior femora, spined tibiæ, elongated face, deeply lobed mesonotum, furrowed mesopleuræ

clearly separated, the third longer than the fourth. Head shining; the face closely, the front and vertex sparsely, covered with short, black hair. Pro- and meso-thorax shining, closely punctured; the median segment coarsely rugosely punctured, sparsely covered with longish black hairs; the metapleuræ rugosely punctured at the sides, the middle with wide, deep, widely separated punctures. The hinder edge of the mesopleuræ crenulated; its base distinctly punctured, the punctures clearly separated, but not by a great distance from each other; the upper part with the punctures closer, smaller and shallower; on the lower side, but not touching the base, is a wide, deep, curved furrow, indistinctly crenulated in the middle. The upper part of the propleuræ stoutly striated; the upper two striæ stout; on the lower side immediately over the coxæ are two much stouter keels. Median segment coarsely rugosely reticulated. Legs entirely fulvous-yellow; the femora sparsely, the tibiæ and tarsi thickly, covered with white hair. Wings hyaline; the stigma large, blackish; the costa and nervures paler; the first abscissa of the radius very short, not one-half the length of the space between the recurrent and the first transverse cubital nervure. The petiole above closely, its apex more sparsely and not so strongly, punctured; the rest of the abdomen very smooth and shining; the apices of the segments pallid-yellow.

The only specimen is not in good condition, but I believe I have described correctly its salient specific points. It appears to be an *Alysia* as defined by Foerster in his generic synopsis of the family. (*Verh. Ver. Rheinl.* XIX. p. 263.)

EVANIIDÆ.

GASTERUPTION PEDUNCULATUM Schl.

Foenus unguiculatus Smith, *Trans. Entom. Soc.*, 1869 p. 480, pl. IV., f. 8.

Gasteruption pedunculatum Schletterer, *Ann. K. K. Natur. Hofmus. Wien*, 1890, p. 467.

One ♂ and one ♀.

In both examples the pronotum is rufous, except in the middle, the rufous colour being narrowest at the top; the mesopleuræ are broadly rufous immediately over the sternum; there is a curved rufous band over the hinder coxæ, and a narrower oblique one immediately in the middle above it. The amount of red on the legs varies. In the ♂ the amount of white pubescence on the prothorax is much greater than it is in the ♀, unless it be that it has been rubbed off from the latter in my specimens.

PROCTOTRUPIDÆ.

PROCTOTRUPES MACULIPENNIS Cam.

Cameron, *Manchester Memoirs*, 1888, p. 175.

One specimen.

MALVINA PUNCTATA Cam.

Manchester Memoirs, 1889, p. 13.

Four examples.

BETYLA FULVA Cam.

Manchester Memoirs, 1889, p. 13.

This species was described by the Rev. T. A. Marshall in the *Entom. Mon. Mag.*, November 1892, under the name of *Tanysonus boletophilus*, which name must give place to my earlier one.

Mr. Marshall describes both sexes. The ♂ is winged, and has the thorax fully developed, not narrow and contracted as in the wingless ♀, which has 15-jointed antennæ, while the ♂ has them 14-jointed, much thinner, attenuated towards the apex, and with the third joint emarginate.

Mr. G. V. Hudson discovered the species at Welling-

ton, New Zealand, to be a parasite on the luminous "Glow Worm" *Bolitophila luminosa. Bolitophila* is a species of Diptera.

FORMICIDÆ.

MONOMORIUM NITIDUM Sm.

Described by Smith as a *Tetramorium.* Common at Greymouth; and, according to Forel, at Mount Cook, on the Island of Timaru, at an elevation of 2,540 feet.

HUBERTIA STRIATA Sm.

This was also erroneously referred to *Tetramorium.* It is more related to *Monomorium;* and a new genus, *Hubertia*, has been formed for its reception by Forel, *C.R. Soc. Entom. Belgique*, 1890. Found at Greymouth and at Mount Cook along with *M. nitidum.*

For an interesting description of the habits of the above-mentioned ants, as observed at Ashburton, the reader is referred to a paper "On the origin of Ants' Nests," by Mr. W. W. Smith in *Entom. Mon. Mag.*, March, 1892, pp. 60-65.* The nests are formed under stones partly buried in the sandy soil, on the terraces of the river and in stony places on the plains.

In the nests of the ants are found sundry inquilines. There are two species of Homoptera a species of *Ripersia* and *Dactylopius poæ* Maskell, both feeding on the roots of the grasses among which the ants' nests are placed; a beetle, *Diarthrocera formicæphila* Brown, an isopod, *Platyarthrus*, and some mites. It is noteworthy that the coccid genus, *Ripersia*, and the crustacean, *Platyarthrus*, are found inhabiting ants' nests in Europe.

PONERA CASTANEA Sm.

Several examples.

* For a description of a great flight of *M. nitidum*, see W. W. Smith, *Entom. Mon. Mag.*, 1890, p. 321.

APHAENOGASTER ANTARCTICUS Sm.

Two females.

FOSSORES.

CRABRO (RHOPALUM) JOCOSUS, *sp. nov.*

Long. 8-9 mm.

Comes near to *C. perforator* Sm.; differs in having less yellow on the legs and none on the mesonotum.

Head black; the cheeks and clypeus densely covered with silvery pubescence; the front and vertex alutaceous, sparsely covered with microscopic down; the ocelli ·.·; the vertex depressed in the centre, where there is a furrow running down from the ocelli; close to the eyes on the inner side, nearly opposite the lower ocellus, is a short, moderately deep, curved depression. Antennæ black; the basal joints of the flagellum testaceous beneath; the third joint slightly, the fourth largely, produced beneath; the sixth deeply incised at the base, the apex largely dilated; the fifth joint ovate. The mandibles piceous before the teeth; there is one large apical and a shorter basal tooth. Pronotum at the middle distinctly separated from the mesothorax; in the centre above broadly hollowed, the sides behind depressed, the middle raised, rounded; the edge of the pronotum near the tegulæ white. Mesonotum and scutellum shining, impunctate, glabrous; a deep, large, oval depression at the side of the post-scutellum. Down the centre of the median segment is a deep, moderately wide furrow. At the base of the mesopleuræ an oblique, wide, crenulated furrow; in the centre above a small round depression; the metapleuræ are broadly depressed at the base. Legs black; the base of the fore femora, the fore tibiæ except a black line behind, the fore tarsi, the apex of the middle femora, the middle tibiæ except behind, the middle tarsi except the apical joint and the second

and third joints of the hinder tarsi, yellow. Wings hyaline; the stigma and nervures black. Abdomen shining; the apical segments covered with short pale hair; the pygidium opaque, covered with longish white hair.

TARANGA.

Under this name Mr. W. F. Kirby (*Trans. Entom. Soc.* 1883, p. 201, fig.) describes a genus *Taranga* "apparently allied to *Pemphredon*" but which is really related to *Pison*. Kohl (*Ann. K. K. Natur. Hofmus. Wien*, XI. p. 458) regards it as a division of *Pison*. Bingham (*Fauna of India, Hym.* i. p. 218) says that he has "taken specimens of *Pison* with three cubital cells in one fore wing, only two in the other. Such seems to be the case with the allied genus *Taranga* Kirby. Kohl unites *Taranga* to *Pison*; but from a careful examination of the type, I have come to the conclusion that they are distinct." I have noticed myself that the outer nervure of the pendicular cellule tends to become obliterated in species where it is normally present. The neuration in *Taranga* appears to be normal, and not merely an individual aberration; but still I cannot regard it in any other light than as a division of *Pison*. Otherwise the species with neuration differing from the type, *e.g.*, *Pisonites*, would also have to be treated as distinct genera.

PISON PRUINOSUS, *sp. nov.*

Niger, opacus, capite thoraceque longe albo-hirtis; alis fere hyalinis. ♀. Long. 16 mm.

Antennæ opaque, the scape and basal joints of the flagellum thickly covered with longish pale hair. Head covered thickly with long greyish hair, which is thicker and more silvery below the eye incision. Apex of clypeus rounded in the middle. Mandibles shining, the base with

long silvery hair. Thorax opaque, alutaceous, thickly covered with longish white hair, longest and thickest on the scutellum and median segment. Apex of the median segment with with an oblique slope; the basal half in the centre with a wide, moderately deep furrow, from which run some curved, oblique keels; the base of the slope coarsely punctured; the rest with strong, transverse, distinctly separated striations. Pleuræ and sternum with small, shallow, distinctly separated punctures; the sternum depressed in the centre, down which runs a straight, stout keel. Coxæ, trochanters and femora covered somewhat thickly with longish white hair; the tibiæ and tarsi pruinose. Wings fusco-hyaline; the extreme apex smoky; the second cubital cellule triangular; in length scarcely half the length of the pedicle; the first recurrent nervure received shortly, but distinctly, in front of the cubital; the second interstitial; the second transverse cubital nervure near the top, and both branches at the bottom are bullated. Abdomen opaque, the segments at the apices banded with silvery pubescence; the basal two ventral segments sparsely covered with white hair; the apical more thickly with longer fuscous hair; the base of the second segment is smooth, raised, and, in the middle, projects into a somewhat triangular area.

P. morosus Sm., is a smaller species than this, has the head, thorax and abdomen more shining, and much less pilose; the furrows on the median segment shorter and shallower; its head is more developed behind; the abdomen deeply excavated in the middle at the base; the depression on the mesopleuræ wider and deeper; the pedicle of the second cubital cellule hardly longer than the appendicular cellule; the second transverse cubital nervure is more rounded and curved at the bottom; the second cubital cellule at the top is hardly so long as the second at the bottom, while in *P. morosus* it is longer;

the transverse nervure is received distinctly in front of the transverse basal; in *P. pruinosus* it is interstitial. *P. tuberculatus* Sm. differs in being much smaller—only 3 lines—and in having two minute tubercles on the second, third and fourth ventral segments near their apical margin.

PISON MOROSUS Sm.•

One specimen.

GORYTES CARBONARIUS Sm.

An example of this, apparently common, species has the second transverse cubital nervure completely obliterated. *Gorytes trichiosoma* Cam. is probably only a form of *G. carbonarius*.

TACHYTES DEPRESSUS Sauss.

Reise der Novara, Hymen. p. 69.
Three specimens.

TACHYTES SERICOPS Sm.

One example.

TACHYTES HELMSI Cam.

Manchester Memoirs, 1888, p. 182.
One example.

POMPILIDÆ.

The *Pompilidæ* appear to be the commonest, largest and most handsome of the New Zealand Hymenoptera. Under the name of *Sphex* one of the species has been recorded by Mr. Potts (probably *S. Wakefieldi*), as preying on spiders, with which the *Pompilidæ* provision their nests. Mr. Potts (*Nature*, XXX. p. 267) says: "A species of *Sphex* [read *Salius*] with orange-coloured body deposits the benumbed or torpid bodies of spiders in some crevice for future use. An individual of this species

had its hole in a dry corner beneath the plate of a long veranda. One day I observed it dragging a victim along a gravelled walk that was parallel to the veranda; the small stones and grit made its progress very difficult. After very trying struggles with these impediments it displayed a remarkable degree of intelligence, by which it gained its ends. It altered its course and made for the veranda, ascending the smooth, painted board that adjoined the gravelled walk. After slowly traversing seven inches of perpendicular, it came to a rounded beading which projected outwards. Now came its supreme moment of physical exertion. The body of the spider apparently was too heavy to render the aid of wings available. After several pauses in its progress it slowly, yet surely, surmounted the difficulty presented by the projecting beading, gained the level boards of the veranda, along which it travelled rapidly with its burden, which it sometimes dragged, sometimes pushed before it. By the expenditure of great exertion in surmounting the beading it gained a smooth and level run to its home of thirty-nine feet."

In Mr. Kirby's Catalogue all the species are described under the name of *Priocnemis*, which name, however, must give place to *Salius*.

a. Fulvous species.

SALIUS WAKEFIELDI Kirby.

This is by far the commonest of the *Pompilidæ*. In a fresh state the head and thorax are thickly covered with golden pubescence; but with age this gets abraded, the parts then appearing quite bare and shining.

SALIUS MARGINATUS Sm.

A much rarer species than *S. Wakefieldi*, to which it has a great resemblance when the latter has the head and

thorax freshly covered with hair. In *S. marginatus*, however, the head and thorax are quite black, instead of brownish or mahogany-coloured, the base of the antennæ black instead of red, while the first and second transverse cubital nervures are curved, in *S. Wakefieldi* straight and oblique.

Under the name of *Agenia brouni*, Signor Gribodo (*Bull. Soc. Entom. Ital.* XVI., 1884) describes a species from Howich, which agrees closely in coloration, &c., with *S. Wakefieldi*, but the latter is a *Salius* not an *Agenia*.

SALIUS FUGAX Fab. (*maculipennis* Sm.).

This is a rare species, and may be known from the others by its smaller size and by having a stigmal as well as an apical fuscous cloud in the wings.

b. Black species.

SALIUS MONACHUS *White* (see *Smith*).

One example of this large species.

SALIUS TRIANGULARIS, *sp. nov.*

Long. 10 mm.

Agrees with *S. monachus* Sm. in being entirely black and in having the head and thorax covered with long black hair, but is not half its size; and otherwise may be readily known from it by the basal abdominal segment being triangular as seen from the side, the centre being sharp, the base and apex falling obliquely, whereas in *S. monachus* the middle is broadly rounded and not sharply differentiated.

Scape of antennæ densely covered with black hair; the second and third joints bare; the rest missing. The head covered all over with long black hair, shining; the apex of the mandibles rufous; the hinder ocelli separated from each other by half the distance they are from the eyes. Thorax covered with longish black hairs; the pro-

and meso-thorax shining; the median segment rounded at the base, the rest oblique; the apex obscurely transversely striated. The femora sparsely covered with longish black hair. Wings with a shining, fuscous tinge; the apex of the radial nervure curved; the second cubital cellule at top and bottom not much more than half the length of the third; the first transverse cubital nervure sharply, the second slightly, oblique; the third roundly elbowed at the middle; the first recurrent nervure received in, the second shortly before, the middle of the cellule. Abdomen shining, impunctate; the basal slope of the petiole covered with longish black hair; the apical more thickly with stouter hair; the apical segment thickly covered with long, stiff, black hair; the hypopygium with the sides broadly rounded; the centre roundly incised.

In certain lights, the wings have a bright, metallic, bronzy iridescence.

SALIUS CARBONARIUS Sm.

Two examples.

SALIUS NITIDIVENTRIS Sm.

A ♂ and ♀.

This is a much smaller species than *S. carbonarius*, and agrees with it in having the body entirely black, shining and almost bare; but may be known from it by having the apex of the cubital nervure curved instead of straight and by the second cubital cellule at the top being distinctly shorter than the third, while in the other species it is equal in length to it.

AGENIA HUTTONI, *sp. nov.*

Nigra, nitida, albo-pruinosa, alis hyalinis, nervis nigris. ♂. Long. 5 mm.

Head, except on the vertex, thickly covered with

silvery pubescence; the eyes very slightly converging beneath, straight; the hinder ocelli separated from each other by a somewhat less distance than they are from the eyes. The three basal joints of the antennæ black, closely covered with white pubescence. Thorax almost shining, thickly covered with short white pubescence; the median segment elongate, rounded. Legs pruinose. Wings as long as the body; the apex of the radial nervure with a slight curve; the second and third cubital cellules at the top as long as the third; the first transverse cubital nervure at the bottom slightly curved, the rest oblique; the first recurrent nervure is received shortly beyond, the second shortly before, the middle of the cellules. Legs entirely black; the femora sparsely covered with white hair; the tibiæ and tarsi with white pubescence, the apex of the hind tibiæ on the inner side with fulvous pubescence. Abdomen shining, impunctate, the apex with short white hair; the hypopygium large, broadly keeled at the base in the middle; the apex rounded, sparsely covered with long white hair.

ANTHOPHILA.

ANDRENIDÆ.

DASYCOLLETES VESTITUS Sm.

Trans. Entom. Soc., 1876, p. 485.
Two specimens.

DASYCOLLETES HIRTIPES Sm.

Trans. Entom. Soc., 1878, p. 7.
One specimen.

PROSOPIS AGILIS Sm.

Trans. Entom. Soc., 1876, p. 484.
One specimen.

PROSOPIS SULCIFRONS, *sp. nov.*

Nigra, nitida, alis fusco-violaceis. ♀. Long. 8-9 mm.

Head shining, the vertex sparsely covered with long blackish, the face more thickly with short white hair; the face with shallow punctures, the vertex at the sides much more distinctly punctured; the centre at and below the ocellar region opaque, alutaceous; the front between the antennæ carinate. On the inside, at the top of the eyes is a deep distinct longitudinal suture. The clypeus at the apex roundly, but not deeply, curved. Mandibles entirely black, deeply and widely furrowed on the outer side; the base alutaceous, the apex shining; the teeth blunt. A curved, shallow, narrow furrow runs down from the antennæ to the bottom of the eyes, bordering the yellow mark; and, in the centre below the antennæ and joining the lateral ones, is a transverse straight one. The flagellum of the antennæ obscure-brownish on the under side towards the apex; closely covered with a pale down; the scape punctured, scarcely dilated towards the apex. On the pronotum is a yellow line, narrowed and almost interrupted in the middle, dilated on the outer side; the tubercles yellow, the latter having at their apex a thick mass of pale hair. Mesonotum distinctly, but not deeply, punctured; there is a central and a lateral narrow, not very distinct, furrow, reaching from the base to the middle. Scutellum punctured like the mesonotum, indistinctly keeled down the middle. Median segment alutaceous, its apex oblique, thickly covered with long white hair. Propleuræ sparsely long white hair; the mesopleuræ bear punctures; the furrow distinctly c- rrow on the median rely black, except and tarsi thickly special rds

silvery pubescence; the eyes very slightly converging beneath, straight; the hinder ocelli separated from each other by a somewhat less distance than they are from the eyes. The three basal joints of the antennæ black, closely covered with white pubescence. Thorax almost shining, thickly covered with short white pubescence; the median segment elongate, rounded. Legs pruinose. Wings as long as the body; the apex of the radial nervure with a slight curve; the second and third cubital cellules at the top as long as the third; the first transverse cubital nervure at the bottom slightly curved, the rest oblique; the first recurrent nervure is received shortly beyond, the second shortly before, the middle of the cellules. Legs entirely black; the femora sparsely covered with white hair; the tibiæ and tarsi with white pubescence, the apex of the hind tibiæ on the inner side with fulvous pubescence. Abdomen shining, impunctate, the apex with short white hair; the hypopygium large, broadly keeled at the base in the middle; the apex rounded, sparsely covered with long white hair.

ANTHOPHILA.

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One specimen.

PROSOPIS SULCIFRONS, *sp. nov.*

Nigra, nitida, alis fusco-violaceis. ♀. Long. 8-9 mm.

Head shining, the vertex sparsely covered with long blackish, the face more thickly with short white hair; the face with shallow punctures, the vertex at the sides much more distinctly punctured; the centre at and below the ocellar region opaque, alutaceous; the front between the antennæ carinate. On the inside, at the top of the eyes is a deep distinct longitudinal suture. The clypeus at the apex roundly, but not deeply, curved. Mandibles entirely black, deeply and widely furrowed on the outer side; the base alutaceous, the apex shining; the teeth blunt. A curved, shallow, narrow furrow runs down from the antennæ to the bottom of the eyes, bordering the yellow mark; and, in the centre below the antennæ and joining the lateral ones, is a transverse straight one. The flagellum of the antennæ obscure-brownish on the under side towards the apex; closely covered with a pale down; the scape punctured, scarcely dilated towards the apex. On the pronotum is a yellow line, narrowed and almost interrupted in the middle, dilated on the outer side; the tubercles yellow, the latter having at their apex a thick mass of pale hair. Mesonotum distinctly, but not deeply, punctured; there is a central and a lateral narrow, not very distinct, furrow, reaching from the base to the middle. Scutellum punctured like the mesonotum, indistinctly keeled down the middle. Median segment alutaceous, its apex oblique, thickly covered with long white hair. Propleuræ sparsely covered with long white hair; the mesopleuræ bearing all over shallow punctures; the furrow distinctly crenulated. The central furrow on the median segment, deep, narrow. Legs entirely black, except the spurs which are pale; the tibiæ and tarsi thickly covered with silvery hair, the tibiæ especially towards

the apex, the femora sparsely covered with soft pale hair; the spurs pale. Wings fuscous, with a violaceous tinge; the stigma and nervures blackish, the former fuscous on the lower side; the second cubital cellule narrowed at the top, being there less in length than the space bounded by the recurrent nervures; the first recurrent nervure is interstitial; the second distinctly separated from the second transverse cubital. Abdomen shining, impunctuate; the apex thickly covered with long black hair. The propleuræ at the base are finely indistinctly obliquely striated.

Comes near to *P. laevigata*; but the description given of its metathorax "smooth", the apex of the abdomen with only "a few black hairs," while in the present species it is thickly covered with long black hairs, does not fit the species here described.

PROSOPIS INNOCENS, *sp. nov.*

Long. 7 mm. ♂.

Comes near to *P. agilis* Sm., but differs in the shorter second cubical cellule, in the recurrent nervures being completely interstitial, in the pronotum being without any yellow, and the tubercles black, not yellow.

Head dull, not shining, the front and vertex obscurely punctured; the clypeus, except the apical margin, yellow, the yellow being produced above it as a wedge-shaped mark, which reaches nearly to the enclosed space below the antennæ, its top being irregular, having one side higher than the other. The inner orbits have a yellow line reaching from near the base of the antennæ, where it is narrow, becoming gradually dilated, rounded, narrowing again to the bottom, but not so narrowly as at the top. The mandibles black on the lower edge, the upper part yellow; the teeth piceous and black. Antennæ stout, black; the basal joints of the flagellum brownish beneath;

the scape curved, only very slightly dilated towards the apex, and obscurely punctured, the lower part fringed with longish pale hairs. Thorax alutaceous, sparsely covered with pale hairs; the mesonotum and mesopleuræ obscurely punctured; the base of the mesopleuræ crenulated; a deep, wide, curved furrow in front of the middle coxæ. On the mesonotum opposite the tegulæ is a curved, shallow furrow. The middle of the median segment has a wide shallow furrow, and bears long pale hair. Legs black, the anterior tibiæ yellow in front; the apices of the anterior tarsal joints testaceous; the tibial spurs pale; the tarsi thickly covered, especially at the base, with pale fulvous hair. Wings hyaline, the stigma black, fuscous on the lower side; the nervures blackish; the first transverse cubical nervure oblique; the second obliquely bent towards it (but not sharply) at the top; the top of the cellule three-fourths of the length of the bottom; the first recurrent nervure almost, the second completely, interstitial. Abdomen dull, the apices of the segment dull-piceous; the apical segments fringed with longish hair.

Abstract of the Greymouth Hymenoptera :—

Ichneumonides	20	Ichneumonidæ
Cryptides	2	
Pimplides	2	
Tryphonides	5	
Ophionides	4	
Braconidæ	3	
Evaniidæ	1	
Proctotrupidæ ...	3	
Formicidæ	4	
Crabronidæ	1	
Larridæ	6	
Pompilidæ	8	
Andrenidæ	5	
Total	64 species.	

Manchester Memoirs, Vol. xlii. (1898), *No.* 2.

II. Description of two new species of *Mutilla* from South Africa.

By PETER CAMERON.

[*Communicated by J. Cosmo Melvill, M.A., F.L.S.*]

Received October 12th. Read November 30th, 1897.

The two species of *Mutilla* here described agree closely in coloration, having the thorax red, the head and abdomen black, the latter having two white marks; but they differ completely in the form of the thorax.

MUTILLA CARSONI, *sp. nov.*

Nigra, longe hirta, thorace rufo; abdominis segmenti secundi maculis duabus albis. Long. 20 mm.

Hab. Island in Lake Tanganyika (*Carson*).

Head black; coarsely rugosely punctured, covered with long black hairs above; the sides below the eyes with silvery pubescence, the oral region with long blackish hair; the palpi blackish. The scape of the antennæ curved towards the apex, sparsely covered with longish black hairs; the flagellum covered with a microscopic pubescence; the basal joints thick, the others distinctly tapering towards the apex. The head is largely developed behind the eyes, being developed there almost twice their length. Thorax three times the length of the head; a little contracted in the middle, gradually narrowed towards the apex; before the depression is a stout, shining, rounded tooth, and behind it are two others of about the same size. The upper part of the mesopleuræ smooth, shining, glabrous; the lower part coarsely punctured; this part being separated above by a distinct raised margin,

and thickly covered with fulvous pubescence and less thickly with long white hair. The apex of the median segment smooth, impunctate. Above, the thorax is covered with long black hairs; the lower part of the metapleuræ thickly covered with pale hairs. Legs thickly covered with long pale hairs; the fore calcaria pale. Abdomen black, thickly covered with long black hairs; before the middle of the second segment are two roundish marks of silvery pubescence; the third segment is covered, except in the middle, with silvery pubescence; the fourth and fifth with long black hairs; the apical with long pale hairs; the basal half of the second ventral segment is stoutly keeled in the middle, the keel ending in a stout, curved, projecting point.

MUTILLA ÆGROTA, *sp. nov.*

Long. 24-25 mm.

Hab. Transvaal.

Agrees in coloration with *M. carsoni;* but the white marks on the second abdominal segment are smaller and situated on the extreme base; otherwise differing in the much shorter and broader thorax which is not one-half the length of the abdomen.

Head strongly rugosely punctured, above sparsely covered with stout black hairs; the oral region, at the sides and behind, with the hairs longer, paler and much more numerous; behind the eyes it is not much longer than them, and straight, not narrowed; the space above the antennæ hollowed, rounded at the top; its sides near the antennæ with a straight stout keel; the clypeus covered with longish, thick, golden hair; the mandibles with longish blackish hair. Antennæ short, thick, not much longer than the width of the head; the scape curved, shining, above sparsely covered with short black hair; the flagellum thick distinctly and gradually narrowed towards

the apex where it is shining and glabrous. Thorax scarcely twice the length of the head, not much narrowed behind; very coarsely rugosely reticulated; the sides irregular; before the middle is a stout tooth; the median segment at the sides, shortly below the top projects into a large, stout, triangular tooth. Legs short and stout (much shorter than in *M. carsoni*); the anterior coxæ and femora thickly, the posterior more sparsely covered with long white hair; the four posterior tibiæ and tarsi thickly covered with stiff silvery hair; the fore tarsi short and thick, above strongly punctured, its lower side with three large stout spines; the apex shining, piceous. The basal two segments of the abdomen nearly as long as the head and thorax united, black; on the extreme base of the second segment are two small silvery marks, broader than long; on either side of the third segment is a large, transverse mark of silvery pubescence; the second segment is strongly punctured, the punctures large, deep, elongate, and running into reticulations; its apex with the punctures very much smaller and more distinctly separated. The basal ventral segment forming a projecting blunt triangle; the base of the second segment oblique, and having a blunt projection in the middle, strongly punctured, especially at the sides where the punctures are much larger, deeper and more irregular; the other segments are much more finely and closely punctured, and thickly fringed at the apex with long pale-fulvous hair. The pygidial area closely rugose; the sides thickly covered with long pale-golden hair; the hypopygium thickly covered with black hair.

Manchester Memoirs, Vol. xlii. (1898), *No.* 3.

III. On Waves in a Medium having a Periodic Discontinuity of Structure.

By Professor HORACE LAMB, M.A., F.R.S.

Received December 6th. Read November 30th, 1897.

The main object of this paper is to illustrate the selective total reflection which takes place at the boundary of a medium of the above constitution. The case where the periodic variation of properties is *continuous* has been discussed by Lord Rayleigh,* but the problem in this form is very difficult, and it may therefore be worth while to investigate in some detail the consequences of the periodic structure in the more tractable circumstances here considered. In the examples chosen for discussion the medium is represented by a string supposed to be capable of longitudinal vibrations, and the periodic interruption of properties consists, in one case, of a series of equal particles attached at equal intervals; in another, these particles are (moreover) urged towards fixed positions by elastic springs; whilst in a third example they are supposed to be connected to the string (not directly but) through the intermediary of springs. It is further shown how the methods can be extended to the case where equal and similar dynamical systems, of any degree of complexity, are inserted at regular intervals. Exactly the same analysis applies when the intervening medium consists of a tense string capable of *transversal* vibrations, and to many other cases.

Experimental illustrations of the principles here

* *Phil. Mag.*, Aug., 1887.

February 4th, 1898.

developed are afforded by some optical and acoustical phenomena studied by Lord Rayleigh;* but the results have also an interest, on another scale, as bearing on mechanical theories of reflection, refraction, &c. In particular, the usual assumption that the wave-length is great compared with molecular intervals, is here dispensed with, and we are able to trace to some extent the fate of a train of relatively short waves, or of an abrupt disturbance. On the other hand, some caution must of course be exercised in drawing inferences as to theories of radiation, absorption, and the like, from the study of a one-dimensional model.

1. Suppose we have a string of line-density ρ, loaded at equal intervals a with particles of mass M. Taking the axis of x along the string, and denoting by ξ the displacement of any point of it, we have the equation

$$\frac{d^2\xi}{dt^2} = c^2 \frac{d^2\xi}{dx^2} \quad . \quad . \quad . \quad . \quad (1),$$

where

$$c^2 = E/\rho \quad . \quad . \quad . \quad . \quad (2),$$

E being the coefficient of elasticity. If we assume that ξ varies as e^{ikct}, *i.e.*, we consider a simple-harmonic disturbance whose wave-length on the unloaded string would be $2\pi/k$, the equation (1) becomes

$$\frac{d^2\xi}{dx^2} + k^2\xi = 0 \quad . \quad . \quad . \quad (3).$$

If we distinguish the values of ξ corresponding to successive particles M by suffixes, the solution of (3) for the interval between the sth and $(s+1)$th particles is obviously

$$\xi = \xi_s \cos kx + \frac{\xi_{s+1} - \xi_s \cos ka}{\sin ka} \sin kx \quad . \quad . \quad (4),$$

* *Phil. Mag.*, Sept., 1888, p. 256; *Theory of Sound* (2nd ed.), vol. ii., p. 311.

where the origin of x has been taken (temporarily) at the undisturbed position of the sth particle. Similarly, in the interval between the $(s-1)$th and sth particles, we have, with the same origin,

$$\xi = \xi_s \cos kx + \frac{\xi_s \cos ka - \xi_{s-1}}{\sin ka} \sin kx \quad . \quad (5).$$

Hence the tensions of the string on the two sides of the sth particle are

$$E\left(\frac{d\xi}{dx}\right)_{x=a} = \frac{kE}{\sin ka}(\xi_{s+1} - \xi_s \cos ka) \quad . \quad (6),$$

and

$$E\left(\frac{d\xi}{dx}\right)_{x=0} = -\frac{kE}{\sin ka}(\xi_s \cos ka - \xi_{s-1}) \quad . \quad (7),$$

respectively. The equation of motion of this particle is therefore

$$M\frac{d^2\xi_s}{dt^2} = \frac{kE}{\sin ka}(\xi_{s+1} - 2\xi_s \cos ka + \xi_{s-1}) \quad . \quad (8),$$

or, since $\xi_s \propto e^{ikst}$,

$$\xi_{s+1} - 2\xi_s(\cos ka - \tfrac{1}{2}\mu ka \sin ka) + \xi_{s-1} = 0 \quad . \quad (9),$$

where

$$\mu = M/\rho a \quad . \quad . \quad . \quad (10),$$

i.e. μ denotes the ratio of the mass of one of the attached particles to that of the portion of string constituting one of the intervals.

The solution of the difference-equation (9) will assume distinct forms according as the coefficient of $2\xi_s$ does or does not lie between the limits ± 1. In the former case we put

$$\cos ka - \tfrac{1}{2}\mu ka \sin ka = \cos\theta \quad . \quad . \quad (11),$$

and we may without loss of generality suppose that θ lies between 0 and π. This gives

$$\xi_s = Ae^{is\theta} + Be^{-is\theta} \quad . \quad . \quad . \quad (12),$$

or, expressing the time-factor,

$$\xi_s = Ae^{i(kst+\epsilon)} + Be^{i(ks-\epsilon)} \quad . \quad . \quad (13),$$

where A, B are independent of s.

In the alternative case we put

$$\cos ka - \tfrac{1}{2}\mu ka \sin ka = \pm \cosh u \quad . \quad (14),$$

where u is real, and obtain

$$\xi_s = Ae^{ikct+su} + Be^{ikct-su} \quad . \quad . \quad (15),$$

or

$$\xi_s = (-)^s\{Ae^{ikct+su} + Be^{ikct-su}\} \quad . \quad (16),$$

according as we take the upper or the lower sign in (14).

The two types of disturbance represented by (13) and (15) or (16) are essentially different in character. Either term of (13) represents a disturbance whose amplitude is the same at all parts of the medium, whilst in the case of (15) or (16) the amplitude of either component diminishes indefinitely as we advance in the medium in one direction or the other. In the former case, the disturbance can be transmitted to any distance; in the latter case, this is not possible. A fuller discussion of this question will be given presently (§ 2).

In the present problem (but not in all the variations of it, see § 5), θ will be real for values of ka falling below a certain limit, and the disturbance will then be of the type (13). Moreover, for very long waves, ka and θ will both be small, and we find, approximately,

$$\theta = \sqrt{(1+\mu)}.ka \quad . \quad . \quad . \quad (17).$$

The disturbance represented by either term of (13) may now be described as a *wave* travelling in the negative or positive direction of x. If the wave-length (λ) in the loaded medium be m times the interval a, where m is a large number, we have $m\theta = 2\pi$, and therefore

$$\lambda = 2\pi a/\theta = ka/\theta.\lambda_0 \quad . \quad . \quad . \quad (18),$$

where $\lambda_0 = 2\pi/k$. Hence, for the refractive index (N) of the medium, we have

$$N = \lambda_0/\lambda = \sqrt{(1+\mu)} \quad . \quad . \quad (19),$$

as we should expect, since the effect of the loads is to

increase the average density of the medium in the ratio $1+\mu$.

If we carry the approximation a stage further, we get the dispersion-formula

$$N^2 = 1 + \mu + \frac{1}{12}\mu^2 k^2 a^2 = N_0^2\left(1 + \frac{1}{3}\frac{\pi^2\mu^2}{1+\mu}\frac{a^2}{\lambda^2}\right) \quad . \quad (20),$$

where N_0 denotes the refractive index for infinite wave-length, as given by (19).

2. We proceed to apply the preceding formulæ to the case of reflection. We will suppose that the string to the left of the origin is unloaded, and that from the origin onwards masses M are attached at equal intervals a, as before.*

An incident wave

$$\xi = e^{ik(ct-x)} \quad . \quad . \quad . \quad (21),$$

in the unloaded portion may be regarded as giving rise to a reflected wave

$$\xi = Ae^{ik(ct+x)} \quad . \quad . \quad . \quad (22),$$

and to a certain disturbance in the loaded medium. When θ is real, and $\sin ka$ positive, this latter disturbance may be represented by

$$\xi_s = Be^{i(kst-s\theta)} \quad . \quad . \quad . \quad (23);$$

and it is proposed to determine the coefficients of reflection and transmission (A and B).

We will suppose that at the origin we have $s=0$. The kinematical condition to be satisfied at this point is

$$1 + A = B \quad . \quad . \quad . \quad (24).$$

The tension of the string immediately to the right of the particle $s=0$ is

$$\frac{kE}{\sin ka}(\xi_1 - \xi_0\cos ka),$$

* The case of sound-waves incident on a series of equidistant perforated screens, as in the experiment described in Lord Rayleigh's *Sound*, § 343, is mathematically equivalent.

and that of the string immediately to the left is

$$(-1+A)ikEe^{ikct}.$$

Hence the dynamical equation is

$$M\frac{d^2\xi_0}{dt^2}=\frac{kE}{\sin ka}(\xi_1-\xi_0\cos ka)+ikE(1-A)e^{ikct} \qquad (25),$$

or,

$$(1-A)e^{ikct}=\frac{\xi_0\cos ka-\xi_1}{i\sin ka}+i\mu ka\xi_0 \quad . \quad . \qquad (26).$$

Substituting the values of ξ_0, ξ_1 from (23), this becomes

$$1-A=B\frac{\cos ka-\mu ka\sin ka-e^{-i\theta}}{i\sin ka}$$

$$=B\frac{e^{i\theta}-\cos ka}{i\sin ka} \quad . \quad . \quad . \quad . \qquad (27),$$

where a reduction has been effected by means of (11).

Solving (24) and (27) for A and B, we find

$$A=\frac{e^{ika}-e^{i\theta}}{e^{i\theta}-e^{-ika}}=\frac{\sin\frac{1}{2}\left(ka-\theta\right)}{\sin\frac{1}{2}\left(ka+\theta\right)}e^{ika} \quad . \qquad (28).$$

$$B=1+A=\frac{\sin ka}{\sin\frac{1}{2}\left(ka+\theta\right)}e^{\frac{1}{2}i(ka-\theta)} \quad . \qquad (29).$$

The amplitude of the reflected wave is therefore

$$\left|\frac{\sin\frac{1}{2}\left(ka-\theta\right)}{\sin\frac{1}{2}\left(ka+\theta\right)}\right| \quad . \quad . \quad . \qquad (30),$$

and that of the disturbance transmitted to the particles M is

$$\left|\frac{\sin ka}{\sin\frac{1}{2}\left(ka+\theta\right)}\right| \quad . \quad . \quad . \qquad (31).$$

For sufficiently long waves, ka and θ are small, and $\theta=Nka$, where N is the refractive index ; the expressions (30) and (31) then take the forms

$$\frac{N-1}{N+1} \quad \text{and} \quad \frac{2}{N+1}.$$

Some caution is necessary in the application of the above results. When θ ceases to be very small, the disturbance in the loaded medium is no longer of the simple character which we are accustomed to associate with the term "wave-motion," and it becomes necessary to consider which of the terms in (13) is to be taken to represent a disturbance progressing in the direction of x-positive. In its present form the problem of this § is indeed, strictly speaking, indeterminate. A more definite form may be given to it if we introduce a very small frictional force, acting on each of the particles M, and proportional to the first power of the velocity. It then appears that the foregoing solution applies when $\sin ka$ is positive, but that when $\sin ka$ is negative, the disturbance in the loaded medium must be represented by

$$\xi = Be^{i(kvt + i\theta)} \quad . \quad . \quad . \quad (32),$$

in place of (23).† The amplitude of the reflected wave is then obtained by reversing the sign of θ in (30).

When θ is imaginary, the formula (23) must be replaced by

$$\xi = Be^{ikvt - u} \quad . \quad . \quad . \quad (33)$$

or

$$\xi = (-)^s Be^{ikvt - u} \quad . \quad . \quad . \quad (34)$$

according as the upper or lower sign obtains in (14). The analytical work is the same as before with the substitution of u or $u - i\pi$ for $i\theta$, and the results can therefore be written down at once. Thus, we find, in the former case,

$$A = \frac{e^{ka} - e^{}}{e^{} - e^{-ka}} = -\frac{(e^{} - \cos ka) - i\sin ka}{(e^{} - \cos ka) + i\sin ka} = -e^{-2i\phi} \quad . \quad (35)$$

where

$$\phi = \tan^{-1}\frac{\sin ka}{e^{} - \cos ka} \quad . \quad . \quad . \quad (36)$$

† It appears unnecessary to go into the proof of these statements, as the more general investigation of the next § is free from the difficulty here indicated.

It appears that the amplitude of the reflected wave is now equal to that of the incident wave. This might have been anticipated from considerations of energy, since (33) shews that for sufficiently large values of s the disturbance to the right of the origin is insensible. The same result will hold, of course, when $i\theta$ is replaced by $u - i\pi$.

3. The next application of our formulæ is suggested by the optical problem: to determine the intensities of the light reflected and transmitted respectively by a *plate*. We will suppose that to the left of the origin the string is unloaded, that a series of masses M are attached at the points

$$x = 0,\ a,\ 2a,\ 3a,\ \ldots\ldots,\ na,$$

and that to the right of the last-named point the string is again unloaded.

It may be sufficient to indicate the leading steps of the calculation. For $x < 0$, the disturbance may be regarded as made up of an incident wave

$$\xi = e^{ik(ct-x)} \quad . \quad . \quad . \quad (37),$$

and a reflected wave

$$\xi = Ae^{ik(ct+x)} \quad . \quad . \quad . \quad (38),$$

as before. For $x > na$, we have a transmitted wave

$$\xi = Be^{ik(ct-x)} \quad . \quad . \quad . \quad (39).$$

The formulæ applicable to the loaded portion of the string will depend on the value of ka. If the value of θ defined by (11) be real, we have

$$\xi_s = Ce^{(ikct - s\theta)} + De^{i(kct + s\theta)} \quad . \quad (40),$$

The kinematical conditions to be satisfied at $x = 0$ and $x = na$ are, respectively,

$$1 + A = C + D \quad . \quad . \quad (41),$$

and

$$Be^{-inka} = Ce^{-in\theta} + De^{in\theta} \quad . \quad . \quad (42).$$

The dynamical equations, analogous to (26), are found to give

$$1 - A = C\frac{e^{i\theta} - \cos ka}{i \sin ka} + D\frac{e^{-i\theta} - \cos ka}{i \sin ka} \quad . \quad (43),$$

and

$$Be^{-ink a} = -C^{-in\theta}\frac{e^{-i\theta} - \cos ka}{i \sin ka} - De^{in\theta}\frac{e^{i\theta} - \cos ka}{i \sin ka} \quad (44).$$

From (41) and (43) we obtain

$$C(e^{i\theta} - e^{-ika}) + D(e^{-i\theta} - e^{-ika}) = 2i \sin ka \quad . \quad (45),$$

$$C(e^{ika} - e^{i\theta}) + D(e^{ika} - e^{-i\theta}) = 2iA \sin ka \quad . \quad (46).$$

Again, from (42) and (44) we find

$$Ce^{-in\theta} = \frac{e^{i\theta} - e^{-ika}}{2i \sin \theta} Be^{-ink a} \quad . \quad . \quad (47),$$

$$De^{in\theta} = \frac{e^{-ika} - e^{-i\theta}}{2i \sin \theta} Be^{-ink a} \quad . \quad . \quad (48).$$

The last four equations may also be written

$$Ce^{\frac{1}{2}i(\theta - ka)} \sin\tfrac{1}{2}(\theta + ka) - De^{-\frac{1}{2}i(\theta + ka)} \sin\tfrac{1}{2}(\theta - ka) = \sin ka \quad (49),$$

$$-Ce^{\frac{1}{2}i(\theta + ka)} \sin\tfrac{1}{2}(\theta - ka) + De^{-\frac{1}{2}i(\theta - ka)} \sin\tfrac{1}{2}(\theta + ka) = A \sin ka \quad (50)$$

$$C = \frac{\sin\frac{1}{2}(\theta + ka)}{\sin \theta} Be^{i(n + \frac{1}{2})(\theta - ka)} \quad . \quad . \quad (51),$$

$$D = \frac{\sin\frac{1}{2}(\theta - ka)}{\sin \theta} Be^{-i(n + \frac{1}{2})(\theta + ka)} \quad . \quad . \quad (52).$$

Substituting from (51) and (52) in (49), we find

$$B = \frac{\sin \theta \sin ka\, e^{i(n+1)ka}}{\sin^2\frac{1}{2}(\theta + ka)\, e^{i(n+1)\theta} - \sin^2\frac{1}{2}(\theta - ka)\, e^{-i(n+1)\theta}}$$

$$= \frac{\sin \theta \sin ka\, e^{i(n+1)ka}}{\sin \theta \sin ka \cos(n+1)\theta + i(1 - \cos \theta \cos ka)\sin(n+1)\theta} \quad (53).$$

The intensity (I) of the transmitted waves, that of the incident waves being taken as unity, is given by the square of the modulus of this expression, and is therefore

$$I = \frac{\sin^2\theta \sin^2 ka}{\sin^2\theta \sin^2 ka \cos^2(n+1)\theta + (1-\cos\theta\cos ka)^2 \sin^2(n+1)\theta} \quad (54)$$

Again, from (50), (51), (52) we find

$$A = \frac{-2i \sin\frac{1}{2}(\theta+ka)\sin\frac{1}{2}(\theta-ka)\sin(n+1)\theta}{\sin\theta\sin ka} Be^{-ina\omega}$$

$$= \frac{i(\cos\theta-\cos ka)\sin(n+1)\theta\, e^{ina\omega}}{\sin\theta\sin ka\cos(n+1)\theta + i(1-\cos\theta\cos ka)\sin(n+1)\theta} \quad (55).$$

The intensity (I') of the reflected waves is therefore given by

$$I' = \frac{(\cos\theta-\cos ka)^2\sin^2(n+1)\theta}{\sin^2\theta\sin^2 ka\cos^2(n+1)\theta + (1-\cos\theta\cos ka)^2\sin^2(n+1)\theta} \quad (56).$$

It is easily verified that

$$I + I' = 1 \quad . \quad . \quad . \quad (57),$$

as should obviously be the case, since there is no dissipation of energy in our medium.

When the number $(n+1)$ of particles in the loaded portion of the string is considerable, a very slight variation in the value of ka (and consequently of θ) will cause great fluctuations in the values of $\cos(n+1)\theta$ and $\sin(n+1)\theta$, and thence in the values of I and I'. The mean value ($\bar{I}$) of the former expression, for wave-lengths in the neighbourhood of $2\pi/k$, is easily calculated* from the formula

$$\frac{2}{\pi}\int_0^{\frac{1}{2}\pi} \frac{d\phi}{\alpha^2\cos^2\phi + \beta^2\sin^2\phi} = \frac{1}{\alpha\beta} \quad . \quad . \quad (58).$$

Thus

$$\bar{I} = \left| \frac{\sin\theta\sin ka}{1-\cos\theta\cos ka} \right| \quad . \quad . \quad . \quad (59),$$

* Cf. Kirchhoff, *Optik*, p. 165.

and the mean value of I' is then

$$\bar{I}' = 1 - \bar{I} \quad . \quad . \quad . \quad (60).$$

We may notice that if q denote the coefficient of reflection, as given by formula (30) of § 2, we have

$$\bar{I} = \frac{1-q^2}{1+q^2}, \qquad \bar{I}' = \frac{2q^2}{1+q^2} \quad . \quad . \quad (61),$$

in accordance with known optical results.

So far, we have supposed θ to be real. When θ is imaginary, the formula (40) must be replaced by

$$\xi = Ce^{ikct - su} + De^{ikct + su} \quad . \quad . \quad (62),$$

or by

$$\xi = Ce^{i(kct + s\sigma) - su} + De^{i(kct + s\sigma) + su} \quad . \quad (63),$$

according as the upper or the lower sign is taken in (14). The rest of the notation being as above, we find in the case of (62)

$$B = \frac{\sinh u \sin ka \, e^{i(n+1)ka}}{\sinh u \sin ka \cosh (n+1)u + i(1 - \cosh u \cos ka)\sinh (n+1)u} \quad \ldots(64),$$

$$A = \frac{i(\cosh u - \cos ka)\sinh (n+1)u \, e^{i ka}}{\sinh u \sin ka \cosh (n+1)u + i(1 - \cosh u \cos ka)\sinh (n+1)u} \quad \ldots(65),$$

these results being obtained at once from (53) and (55) by writing $\theta = -iu$. When nu is great, we may put

$$\cosh (n+1)u = \sinh (n+1)u = \infty,$$

which gives

$$B = 0, \quad A = \frac{i(\cosh u - \cos ka)e^{iha}}{\sinh u \sin ka + i(1 - \cosh u \cos ka)}. \quad (66).$$

The modulus of the latter expression, which is, moreover, easily indentified with (35), is unity. The incident wave is now reflected with unchanged amplitude, and there is no transmitted wave.

4. It remains to examine for what ranges of ka the incident wave in the problem of § 2 is partially transmitted, or wholly reflected, respectively. For this purpose we

require to know the critical values of ka, viz., those which make

$$\cos ka - \tfrac{1}{2}\mu ka \sin ka = \pm 1 \quad . \quad . \quad (67).$$

This equation requires that either

$$\sin ka = 0 \quad . \quad . \quad . \quad (68),$$

or

$$\cot \tfrac{1}{2}ka = \tfrac{1}{2}\mu ka \quad . \quad . \quad , \quad (69),$$

or

$$\tan \tfrac{1}{2}ka = -\tfrac{1}{2}\mu ka \quad . \quad . \quad (70).$$

The roots of (69) and (70) are easily constructed graphically by means of the intersections of the curves

$$y = \cot \tfrac{1}{2}x, \quad y = -\tan \tfrac{1}{2}x \quad . \quad . \quad (71),$$

(where $x = ka$) with the straight line

$$y = \tfrac{1}{2}\mu x \quad . \quad . \quad . \quad . \quad (72).$$

The positive roots of (68) are given by

$$ka = 0, \ \pi, \ 2\pi, \ 3\pi, \ldots\ldots$$

We will denote the positive roots of (69) by

$$ka = a_1, \ a_2, \ a_3, \ldots\ldots \ ,$$

and those of (70) by

$$ka = \beta_1, \ \beta_2, \ \beta_3, \ldots\ldots$$

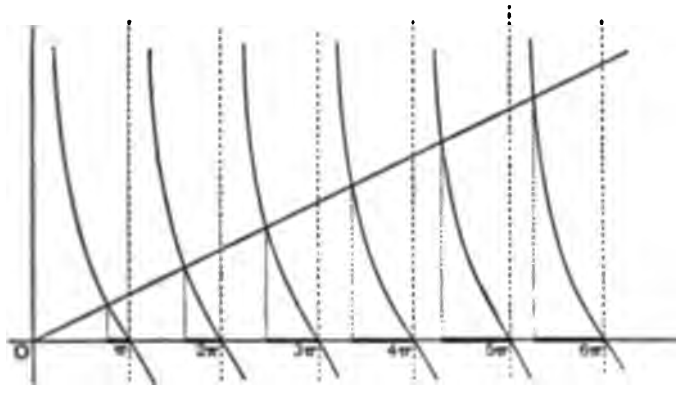
It appears on reference to the figure that the positive roots of (67), when arranged in ascending order of magnitude, are given by the first line of the following scheme:

$$\left.\begin{array}{l} ka = \overbrace{0,}\ \overbrace{a_1,}\ \overbrace{\pi,}\ \overbrace{\beta_1,}\ \overbrace{2\pi,}\ \overbrace{a_2,}\ \overbrace{3\pi,}\ \overbrace{\beta_2,}\ \ldots \\ \theta = 0,\ \underbrace{\pi,}\ \underbrace{\pi,}\ \underbrace{0,}\ \underbrace{0,}\ \underbrace{\pi,}\ \underbrace{\pi,}\ \underbrace{0}\ \ldots \end{array}\right\} \quad . \quad (73),$$

and it is easily ascertained that the equation in question has no multiple roots. Hence each of the roots in (73) marks a transition from partial transmission to total reflection, or *vice versâ*. The upper brackets indicate the ranges of ka for which there is partial transmission, and the lower ones mark the intervals of total reflection.

If the masses M be increased, the straight line

$y = \frac{1}{2}\mu x$ becomes steeper, and the intervals of total reflection, which are indicated by the heavier portions of the axis of x in the figure, widen out at the expense of those of partial transmission.



In interpreting these results we must remember that the quantity ka is inversely proportional to the wave-length, and therefore directly proportional to the frequency, of the incident vibrations.

To estimate the maximum amplitude of the transmitted waves, in any interval of partial transmission, we remark that the value of θ in any such interval ranges between the limits 0 and π. If we put $\theta = \frac{1}{2}\pi$, the formula (59) of § 3 gives

$$T = |\sin ka| \quad . \quad . \quad (74)$$

Also, putting $\theta = \frac{1}{2}\pi$ in (11), we have

$$\tan ka = -\frac{2}{\mu ka} \quad . \quad . \quad (75)$$

Hence, near the centres of the intervals of higher order we have

$$ka = s\pi + \epsilon,$$

where ϵ is small, and

$$T = \epsilon,$$

approximately. We infer that in the successive intervals of partial transmission the amplitude of the transmitted

vibrations becomes less and less. Moreover, it is easily seen that this tendency is more marked, the greater the value of μ.

5. As a first variation of the problem stated in § 1 we will suppose that each of the masses M, in addition to the forces which it experiences from the string on the two sides of it, is urged towards its mean position by means of a spring.

The equation of motion of the sth particle is then of the form

$$M\frac{d^2\xi_s}{dt^2} = \frac{kE}{\sin ka}(\xi_{s+1} - 2\xi_s \cos ka + \xi_{s-1}) - M\sigma^2\xi_s \quad . \quad (76)$$

or since $\xi \propto e^{ikct}$,

$$\xi_{s+1} - 2\xi_s\left\{\cos ka - \tfrac{1}{2}\mu\left(ka - \frac{\sigma^2a^2}{c^2}\cdot\frac{1}{ka}\right)\sin ka\right\} + \xi_{s-1} = 0 \quad (77).$$

The constant σ here denotes the 'speed' of the oscillation when M vibrates under the influence of the spring alone.

The expression whose value determines the character of the motion is now

$$\cos ka - \tfrac{1}{2}\mu\left(ka - \frac{\sigma^2a^2}{c^2}\cdot\frac{1}{ka}\right)\sin ka \quad . \quad . \quad (78).$$

If this lie between the limits ± 1 we have in the problem of § 2 a partial transmission; in the opposite case a total reflection.

The limiting value of (78) for $ka = 0$ is

$$1 + \tfrac{1}{2}\mu\sigma^2a^2/c^2,$$

and therefore greater than unity. It follows that for frequencies below a certain limit, or for lengths of the incident waves exceeding a certain limit, we shall have total reflection. The fact that in a medium of the kind here considered there is an *upper* limit to the length of waves which can be transmitted is very remarkable.

The critical values of ka are determined by the equation

$$\cos ka - \tfrac{1}{2}\mu\left(ka - \frac{\sigma^2 a^2}{c^2}\cdot\frac{1}{ka}\right)\sin ka = \pm 1 \quad . \quad (79).$$

This requires either that

$$\sin ka = 0 \quad . \quad . \quad . \quad (80),$$

or that

$$\tan \tfrac{1}{2}ka = -\tfrac{1}{2}\mu\left(ka - \frac{\sigma^2 a^2}{c^2}\,\frac{1}{ka}\right) \quad . \quad . \quad (81),$$

or that

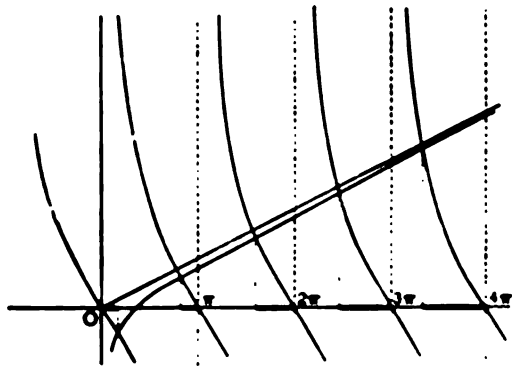
$$\cot \tfrac{1}{2}ka = \tfrac{1}{2}\mu\left(ka - \frac{\sigma^2 a^2}{c^2}\,\frac{1}{ka}\right) \quad . \quad . \quad (82).$$

The positive roots of (81) and (82) are determined graphically by the intersection of the curves

$$y = -\tan \tfrac{1}{2}x, \quad y = \cot \tfrac{1}{2}x \quad . \quad . \quad (83),$$

with the hyperbola

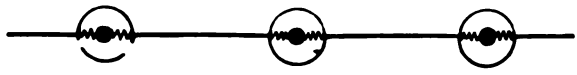
$$y = \tfrac{1}{2}\mu\left(x - \frac{\sigma^2 a^2}{c^2}\,\frac{1}{x}\right) \quad . \quad . \quad . \quad (84).$$



We have now total reflection throughout the range extending from $ka = 0$ to $ka = \beta_0$, where β_0 is the lowest positive root of (81). For large values of x the hyperbola (84) approaches the asymptote $y = \frac{1}{2}\mu x$, and the critical values of ka approximate to those determined in § 4. It will be noted that no special peculiarity attaches

to the case of $ka = \sigma a/c$, which occurs always in an interval of partial transmission.

6. An instructive contrast to the state of things considered in § 5 is obtained if we suppose the masses M to have an elastic connection with the vibrating string. In the annexed illustration, each of the circles is meant to represent a light rigid frame, attached to the string at opposite ends of a diameter, and carrying a particle M connected with it by springs.



Some addition to our previous notation is now required. We will denote by ξ_s the displacement of the point of the string to which one of the masses is attached, and by ξ_s' that of the corresponding particle. We have then

$$M\frac{d^2\xi_s'}{dt^2} + M\sigma^2(\xi_s' - \xi_s) = 0 \quad . \quad . \quad (85),$$

whilst, from the equilibrium of tensions,

$$\frac{kE}{\sin ka}(\xi_{s+1} - \xi_s \cos ka) - \frac{kE}{\sin ka}(\xi_s \cos ka - \xi_{s-1}) + M\sigma^2(\xi_s' - \xi_s) = 0 \quad (86)$$

Assuming that $\xi' \propto e^{ikct}$, and eliminating ξ_s', we find

$$\xi_{s+1} - 2\xi_s\left(\cos ka - \frac{\frac{1}{2}\mu ka}{1 - k^2c^2/\sigma^2}\sin ka\right) + \xi_{s-1} = 0 \qquad (87).$$

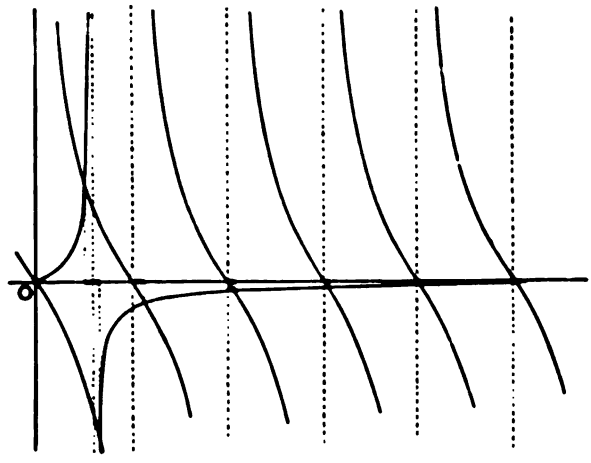
For sufficiently small values of ka we now have transmission, as in § 2. The critical values of ka are given by

$$\cos ka - \frac{\frac{1}{2}\mu ka}{1 - k^2c^2/\sigma^2}\sin ka = \pm 1 \quad . \quad (88).$$

This is satisfied by $\sin ka = 0$, and the remaining roots are determined by the intersection of the curves (83) with the curve

This has an asymptote parallel to y for $x = \sigma a/c$, or $kc = \sigma$.

$$y = \frac{\frac{1}{2}\mu x}{1 - \frac{x^2}{\sigma^2 a^2/c^2}} \quad . \quad . \quad . \quad (89).$$



It appears that waves whose length (λ_2) exceeds a certain limit ($<2a$) are partially transmitted. Moreover, for sufficiently long waves we find

$$N = \nu'(1+\mu) \quad . \quad . \quad . \quad (90)$$

exactly as in § 1. As the wave-length is diminished we get a series of alternate intervals of total reflection and partial transmission, respectively. But the intervals of partial transmission become wider and wider as we proceed, so that our medium is transparent for relatively short waves, except when the wave-length falls a little short of an aliquot part of $2a$. Moreover, in the middle of any one of these intervals, of high order, we have $\theta = \frac{1}{2}\pi$ and $\sin ka = \pm 1$, approximately.* It follows from (59), that the coefficient of transmission is then nearly equal to unity.

We have here perhaps an illustration of the theory of refraction sketched by Sir George Stokes in the Wilde lecture† At all events, we have constructed a one-

* The angle ϕ is now defined by the equation

$$\cos ka \quad \frac{\frac{1}{2}\mu ka}{1 \quad \quad} \sin ka = \cos\theta$$

In the investigations of §§ 2, 3 we have only to write $\mu/\{1-k^2\cdot\frac{1}{3}a^2\}$ for μ throughout. The results, such as (30), (31), and (50), from which μ has been eliminated, will remain unaltered.

† *Manchester Memoirs*, vol. xli. (1897), No. 15.

dimensional medium which for sufficiently long waves has a definite index of refraction, with coefficients of reflection and transmission related to this index in the usual manner; which (again) totally reflects radiations of wave-lengths lying between certain limits; whilst for sufficiently short waves there is, as a rule, free transmission, with practically no reflection.

7. The above examples have been chosen for simplicity, but there is no difficulty in extending the method to the case where dynamical systems of any degree of complexity, but all exactly alike, are interpolated at regular intervals.

We may suppose that the position and configuration of any one of these systems is determined by means of the coordinate (ξ) of the point of the string where it is attached, and by means of n other coordinates $q_1, q_2, \ldots q_n$. There is no loss of generality in supposing these latter coordinates to be so chosen that the expressions for the kinetic and potential energies reduce to the forms

$$2T = a_1\dot{q}_1^2 + a_2\dot{q}_2^2 + \ldots + a_n\dot{q}_n^2 + 2(a_1\dot{q}_1 + a_2\dot{q}_2 + \ldots + a_n\dot{q}_n)\dot{\xi} + P\dot{\xi}^2 \quad \ldots(91),$$

and

$$2V = b_1q_1^2 + b_2q_2^2 + \ldots + b_nq_n^2 + 2(\beta_1q_1 + \beta_2q_2 + \ldots + \beta_nq_n)\xi + Q\xi^2 \quad \ldots(92),$$

respectively. Lagrange's method then gives n equations of the type

$$a_r\ddot{q}_r + b_rq_r + \alpha_r\ddot{\xi} + \beta_r\xi = 0 \quad . \quad . \quad (93),$$

together with

$$P\ddot{\xi} + Q\xi + \Sigma_r(\alpha_r\ddot{q}_r + \beta_rq_r) = X \quad . \quad . \quad (94),$$

where X is the extraneous force corresponding to the coordinate ξ, viz., the difference of tensions on the two sides of the interruption. If we assume that all our functions vary as e^{ipct}, we have, from (93),

$$q_r = -\frac{k^2c^2a_r - \beta_r}{k^2c^2a_r - b_r}\xi \quad . \quad . \quad . \quad (95),$$

and thence, from (94),

$$\left\{ k^2c^2P - Q - \Sigma_r \frac{(k^2c^2a_r - \beta_r)^2}{k^2c^2a_r - b_r} \right\} \xi = -X \quad . \quad (96).$$

We have a formula of this type for each interpolated system. Distinguishing the successive systems by suffixes, we have, from (6) and (7),

$$X_s = \frac{kE}{\sin ka}(\xi_{s+1} - 2\xi_s \cos ka + \xi_{s-1}) \quad . \quad (97),$$

and therefore

$$\xi_{s+1} - 2\{\cos ka - f(k)\sin ka\}\xi_s + \xi_{s-1} = 0 \quad . \quad (98),$$

where

$$f(k) = \frac{1}{2kE}\left\{ k^2c^2P - Q - \Sigma_r \frac{(k^2c^2a_r - \beta_r)^2}{k^2c^2a_r - b_r} \right\} \quad . \quad (99).$$

The difference-equation (98) is to be solved as before. The critical values of k are determined by

$$\cos ka - f(k)\sin ka = \pm 1 \quad . \quad . \quad (100)$$

and are therefore given graphically by the intersections of the curves

$$y = \cot \tfrac{1}{2}x, \quad y = -\tan \tfrac{1}{2}x \quad . \quad . \quad (101)$$

with the curve

$$y = f(x/a) \quad . \quad . \quad . \quad (102).$$

The latter curve has asymptotes parallel to y corresponding to

$$kc = (b_r/a_r)^{\frac{1}{2}}, \quad [r = 1, 2, \ldots n] \quad . \quad . \quad (103).$$

It is not difficult to establish that these special values of k will occur always in intervals of total reflection.

It may be shewn also that the terminal conditions, in the problems of §§ 2, 3, reduce to the forms given in equations (24), (27), and (41)...(44), and thence that the expressions obtained in § 3 for the coefficients of reflection and transmission in terms of ka and θ are perfectly general.

The problem may be still further generalized by imagining each interpolated system to have two distinct points of attachment, on opposite sides, to the interrupted string. The simplest example of this kind is where each system consists of two equal masses connected by a spring.

A dynamically equivalent problem is that of the propagation of sound-waves along a tube having a series of equidistant bulbous expansions. The difference-equation is

found, on examination, to be of the same general type (98) as before.

Manchester Memoirs, Vol. xlii. (1898), *No.* **4.**

IV. Further investigations into the Molluscan Fauna of the Arabian Sea, Persian Gulf, and Gulf of Oman, with descriptions of Forty species.

(Mostly dredged by F. W. Townsend, Esq.)

By JAMES COSMO MELVILL, M.A., F.L.S.

Received and read December 14th, 1897.

Referring to my first paper* on this subject, read exactly a year ago (December, 1896), before this Society, I had the pleasure of meeting Mr. Townsend in London last summer, and of examining carefully with him the whole of the material collected by him during the past four years. He has now returned to India, and is contemplating, if possible, seeking fresh areas for research and for dredging purposes, and hopes to be able to sound depths exceeding those compassed by him in former expeditions. His last best results came from the Bahrein Islands, and the southern shores and inlets of the Persian Gulf. From the neighbourhood of Bushire to the north, and especially from the two islands Kais (or Gais) and Sheikh Shuaib, some very prolific material was dredged.

The principal novelties are, a most exquisite *Ostrea*, perhaps the most delicately beautiful of the genus yet discovered, a handsome *Trochus*, allied to *T. radiatus*, two new cones, one of these, *C. saecularis*, we trust to receive live examples of, and augur that, in perfect condition, it will hardly yield the palm for perfection of form and graceful outline to any other species. Another *Yoldia* has occurred, a wonderfully pure crystalline shell, a *Drillia*

* *Manchester Memoirs*, Vol. xli., No. 7, 1897.

May 17th, 1898.

(*D. resplendens*) unique for fine polish and brilliant colouring, two *Bullia*, one (*B. ceroplasta*) peculiar and unusual in form, a pretty Scalaria (*S. malcolmensis*) from Malcolm Inlet, on the S. of the Persian Gulf, and *Fusus arabicus*, a dwarf species of typical form and character, from Muscat, where also occurred the striking *Mytilicardia Ffinchi*, which, at the request of Mr. Townsend, we have named after Mr. B. T. Ffinch, C.I.E., chief of the staff of the Indo-Oceanic Telegraph Service. Two more examples, also, of the beautiful *Scalaria fimbriolata* Melv., having occurred off Muscat, the largest (a remarkably perfect example measuring 52 mm. in length, and well preserving the salient characters of the original description, by which it was differentiated from *S. decussata* Kien) is here figured (Pl. 1, f. 12). But, of all the forms, a new *Strombus* is perhaps the most unlooked for. It is now very many years since any additions were made to this genus, and monographers have considered it complete. The species, therefore, for which I propose the name *belutschiensis*, dredged off Charbar, on the coast of Beluchistan, is therefore exceedingly noteworthy. It only came to hand during the preparation of the present paper, and may be regarded as the first fruits of Mr. Townsend's fresh dredging expedition (1898).

I have also included in the present paper certain new species dredged by Captain Tindall, of the S.S. "Patrick Stewart," either on the Angrias Bank, W. of Bombay, at Quilon, on the Malabar Coast, or near Batticaloa and Hambangtotte, E. and S. Ceylon respectively. From the two former, especially, came some good results, *e.g.*, *Ancilla Tindalli*, a distinct addition to a circumscribed genus, *Marginella quilonica*, an elegantly banded shell, and *Calliostoma duricastellum*, this last dredged abundantly at Batticaloa. One example of the true *Scalaria decussata* Kien, was also dredged off the Angrias Bank.

I am indebted, too, to Mr. G. B. Sowerby for letting me inspect a few Mollusca collected on the Mekran Coast and in the neighbourhood of Karachi by Mr. J. O. Twells, one of which, a toothless *Nerita*, seems undescribed.

As heretofore, to Mr. Ernest R. Sykes, Mr. E. A. Smith, and especially Mr. Hugh Fulton, very best acknowledgments are due. The latter has much aided me with close examination of critical forms. Mr. Robert Standen has also been most kind in his help, and I am much obliged to him.

It will not, I think, be amiss here to print in extenso a short account of Mr. Townsend's collecting grounds, supplied to me by him, and given in his own words, as follows:

"The extent of the Mekran Coast does not seem to be generally realized, comprising, as it does, over 500 miles of coast in a direct E. and W. line, Karachi being at the Eastern, and Jask at the Western extremity. It naturally follows that only a very few spots have been exploited, and, with the exception of Karachi, it cannot be said that even now any one place has been thoroughly worked out. Karachi offers a fairly rich field to the collector, considering its limited area, both as regards littoral and dredged species, the number already named and classified being about 750, and there are still many unidentified species, which do not appear in the list, and which are now being gradually worked out.

"The extensive mud flats of the Karachi Harbour backwater have not, so far, yielded many varieties, but this may be due to the fact that they have been but slightly investigated. The mud is mostly of a very soft nature, and the labour entailed by *walking* even a short distance is very great, and to that may be added the risk of contracting malarial fever by stirring up noxious gases. The reefs to the west of the harbour are composed of

sandstone, in which several kinds of borers are common, and, though not nearly as rich in results as might be expected from their situation and appearance, yet some of the species found there are exceptionally fine. For instance, *Cypræa lentiginosa*, *C. pallida*, *C. turdus*. The loose stones of the training groin inside the harbour furnish very similar species, but they are not, as a rule, so fine in colour or size as those found on the reef. This may be due to the fact that the stones forming the groin are in a more or less muddy and dirty state, whilst the reef is free from mud and deposit from the harbour.

"The sandy beach, which extends for miles, is even less productive than the rocks, the few species found there being common and uninteresting. As will be seen, whenever the list we are contemplating is published, the majority of the Karachi species have been obtained by dredging. The most profitable ground for this kind of work is a mixture of sand and mud with loose stones, in the immediate vicinity of rocky patches or reefs. Different kinds of softish mud also yield good results, but not without much labour, as the dredge fills quickly, and so the contents take some time to sift. There is a good deal of shingle about Karachi, the worst of all bottoms, as the dredge is filled at once with stuff that cannot be sifted, and is seldom worth careful examination.

"Before passing from Karachi, it may be worth noting the manner in which the fishermen obtain quantities of *Solen corneus*, which they use for bait for certain kinds of fish. A pointed stick about two feet long is introduced into one of the holes with which the mud flats abound, and, should an obstruction be felt, is quickly withdrawn and a pinch of common salt dropped into the hole. The stick is then re-inserted, and twirled rapidly and lightly between the palms of the hands until an upward movement is felt and the fish appears, more than half the shell sometimes protruding above the surface of the mud.

"*Placuna placenta*, which seems to be common both on the Mekran Coast and in the Persian Gulf, is preserved at Karachi and in the neighbourhood, and is a source of revenue to the Indian Government, the right to collect them for the pearls they may contain being sold every few years. No edible bivalves are collected at Karachi for the market, as at Bombay.

"West of Karachi, almost all the species given in the list have been dredged in depths varying from 5 to 60 fathoms, soft mud, muddy sand, and hard clayey mud being the kind of bottom usually met with. A few isolated patches of soft muddy sand, with loose stones, have been found at a depth of about 7 fathoms, and these are always profitable to dredge over—whilst, on the other hand, the hard clayey mud is not only utterly unprofitable as regards living specimens, but is very troublesome in choking the dredge.

"The chief features of the Mekran Coast vary very little—high, rugged hills, both in the fore and back ground, with occasional valleys, the whole presenting as barren and desolate an appearance as it is possible to imagine. The whole of this coast has undoubtedly formed part of the sea bottom at some prehistoric age, as the highest hills are covered with a layer of hard stony substance, which has originally been mud, and in which are found quantities of shells in a more or less fossilized state. On the Gwadur Headland, 480 feet above sea level, large specimens of *Eburna Molliana* in an almost perfect state have been found, the colouring in one instance being almost as fresh as that of a living specimen. Large numbers of single valves of *Pecten Testonsendi* have also been found in the same place in an equally good condition, in fact the whole of the Mekran Coast and Persian Gulf offers a rich field to geologists. Several of the rocky reefs between high and low watermark, and the long stretches

of sandy beach which are exposed to the full force of the S.W. monsoon, have been examined, but they are usually as devoid of shells as the surrounding country is of vegetation; it is only in sheltered nooks that anything like success has rewarded the most diligent search. The coast line of the Persian Gulf is about three times the length of Mekran Coast, and has been even less explored. Opportunities of landing at any but the regular ports of call are few, although more dredging has been done in the Gulf; it is again only in the sheltered corners that any spoils can be obtained. One live coral reef, at Bahrein, was examined at low water, but yielded nothing beyond *Murex spinosus* and *Turbo radiatus*, both common species.

"The bed of the Gulf is chiefly composed of blue mud, at a depth of from 40 to 50 fathoms, decreasing, as the head of the Gulf is reached, to 30 and 20 fathoms. Although live specimens are seldom met with, the mud contains large quantities of dead shells, and these, it may be presumed, in a living state, inhabit the rocky patches and coral which abound in all parts, becoming scattered by the action of currents, hermit crabs, etc. The best results, in dredging, have been achieved round the various islands in from 7 to 12 fathoms; the bottom, in these localities, is mainly composed of coral, live and dead, sand and weeds; the little mud there is being mixed with sand and loose stones.

"One interesting fact has been observed in the Persian Gulf, and in a less degree on the Mekran Coast. The submarine telegraph cable belonging to the Indian Government (from Karachi to Jask a single line, from Jask to Bushire two lines), lies principally upon the mud, in about 45 fathoms. Upon raising the cable for repairs, in any part, it is generally found to be covered with shell growth, varying in quantity and thickness according to the length of time the cable has remained undisturbed.

Strange to say, however, nothing living can be dredged near it, therefore could the cable be seen at the bottom of the sea it would present the appearance of a long line of oysters and other shell growth interspersed with weeds, passing over a vast field of mud.

"The dredge used in making the collection is of wire netting, the bag having an iron mouth, for boat use; the mouth would be 2ft. × 6in. made of flat iron (2in. × ¼in.), the top and bottom being flattened out and made sharp, the wire net bag about 2ft. deep, with ¼in. mesh. The rope for towing is attached to a chain bridle, made fast to to the four corners of the frame."

LEUCOTINA GRATIOSA, *sp. nov.*

(Pl. 2, f. 15.)

L. testa attenuato-fusiformi, albida, ochraceotincta, delicata, tenui, anfractibus octo, ventricosulis, undique spiraliter arcté punctato-sulculosis, apertura oblonga, labro simplici, margine columellari intus uniplicato.

Long. 13·50, lat. 4 mm.

Hab. Malcolm Inlet, Persian Gulf, 10-12 fathoms.

A whitish shell, tinged with pale ochreous; attenuately fusiform, eight-whorled, whorls somewhat swollen, spirally closely punctate, the punctuations stained with pale ochre, mouth oblong, lip simple, columella internally once-plaited.

A very graceful shell, and evidently a *Leucotina*, though at one time we had fancied it came nearer *Actæopyramis*. Much confusion exists at present as to the limitation of these two genera, and no solution will be found to this difficulty till the animal is studied, when, naturally, the wide distinction between the opisthobranchiate *Actæonidæ* as compared with the *Pyramidellidæ*, will be seen at once. Conchologically, the chief distinction seems to be in *Leucotina*, the uniform punctate

sulcation, and the columellar plait. The sulcations in such species as *Monoptygma fulva*, and *Myonia concinna* now relegated to *Actæopyramis*, are simple, and non-puncturate.

(*gratiosus*, benign.)

TORNATINA TOWNSENDI, *sp. nov.*

(Pl. 1, f. 20.)

T. testa cylindracea, delicata, papyracea, albida, vel pallidé straminea, omninó lævi, parum nitente, anfractibus quatuor, apud suturas canaliculatis, apicali mammillato, vitreo, ultimo magnoperé cæteros superante, lateribus rectis, apertura oblonga, apud basim latiore, labro recto, tenui, simplici.

Long. 3·50, lat. 1·50 mm.

Hab. Karachi.

Cylindrical, papyraceous, thin, with straight sides, four-whorled, including the glassy nipple-shaped apical, the shell being entirely smooth, though hardly shining, deeply channelled at the sutures, the last whorl ten times exceeding the size of the others put together. Dredged abundantly near Karachi; we have seen quite a hundred specimens. It is allied to *T. fusiformis* A. Ad. from Japan, also to *T. Isseli* Pilsbry (=*pygmæa* Issel), which occurs with it, but not plentifully.

TEREBRA EDGARII, *sp. nov.*

(Pl. 2, f. 12.)

T. testa attenuata, angusta, solidiuscula, cinereofusca, haud nitente, anfractibus tredecim quorum apicali lævi, subvitreo, cæteris apud suturas impressis, paullulum gradatulis, spiraliter zona suturali succinctis, undique longitudinaliter et irregulariter costulatis, costis rudibus, lævibus, interstitiis planis, cinereis, ultimo anfractu dorsaliter transversim infra medium albizonato, apertura squarrosé

ovata, intus fusca, spiraliter albizonata, labro simplici, columella fusca, nitida.

Long. 19, lat 4·50 mm., *sp. maj.*

Hab. Karachi.

A few specimens of an attenuate, solid, dull grey *Terebra*, with fuscous rudely sculptured ribs, which are smooth and slightly shining, relieving (at all events in the larger examples before us) the dull unicolorous interstices. The sutured band is broad and well defined, the whorls thirteen, inclusive of the glassy apical whorl, the last has dorsally a whitish spiral zone encircling it, which appears reflected inside the mouth. The outer lip is simple, columella shining, fuscous. We dedicate this species to Mr. Edgar Smith, who has done more of late years than any other author to elucidate the genus, He considers it near *T. prætexta* Conr. and *T. evoluta* Desh., this latter by some being considered a variety of the large *T. Dussumierii* Kien. Mr. Hugh Fulton has also taken much trouble in the differentiation of this species, also considering it near *evoluta*, and for his care I am much indebted.

CONUS (LEPTOCONUS) DICTATOR *sp. nov.*

(Pl. 1, f. 10.)

C. testa fusiformi, oblonga, spira multum elevata, apice acutissimo, anfractibus duodecim, apicalibus lævibus, ferè pellucidis, cæteris gradatulis, albidis, arcté brunneosparsis et maculatis, ultimo anfractu apud peripheriam acutangulari, lateribus rectis, parum nitente, undique transversim sulcato, sulcatis arcté puncturatis, omni superficie brunneosparsa, flammulata, vel (præcipué apud medium) maculata, apertura angusta, labro tenui, simplici, recto, basi paullum recurva.

Long. 47, lat. 20 mm.

Hab. Sheikh Shuaib Island, Persian Gulf, 10 fathoms in coral sand.

The nearest allies to this cone are *C. tornatus* Brod.,

(wrongly joined to *interruptus* Brod. (*Ximenes* Gray), by Tryon, both being natives of the west coast of Central America), and *C. planiliratus* Sowb. This last has been newly figured by Smith, it having been dredged in the "Investigator" Expedition, off Calicut, west coast of S. India, in 45 fathoms. (*c.f. Ann. & Mag. N.H.* Series 6, vol. xiv., p. 159, 1894.) Our shell is more elegantly spindle-shaped, and the spiral grooves are less distant and puncturate. *C. dictator* is fusiform, with elevated spire, acute apical whorls, attenuate base, straight sides, angled periphery, dull white colour, everywhere dotted and painted with dark brown; these markings on the last whorl break out into longitudinal brown flames, and there is another suffusion of brown below the middle. This whorl is likewise transversely encircled with lined furrows, which are closely puncturate. The mouth is narrow, outer lip simple. One perfect specimen.

CONUS (LEPTOCONUS) SÆCULARIS, *sp. nov.*

(Pl. 1, f. 23.)

C. testa gracili, arcuato-fusiformi, spira elevata, apice acutissimo, anfractibus tredecim, arctis, gradatis, tribus apicalibus pervitreis, lævibus, cæteris infrá suturas stramineo-sparsis, pulchré cancellatis, et tornatis, ultimo anfractu arcuato, stramineo, nitido, ad peripheriam acutangulari, albo, rubrimaculato, infrá hic illic, et præcipué apud medium albosparso et maculato, simul ac prope basim, basi multum attenuata, undique transversim arctissimé sulculoso, sulculis puncturatis, apertura angusta, labro simplici.

Long. *spec. maj.* 36, lat. 13 mm.

Loc. Malcolm Inlet, Persian Gulf, 24 fathoms mud.

One of the most gracefully beautiful of the genus. Several individuals were discovered by Mr. Townsend at the locality above cited, none, however, in live condition, and only two (one especially) showing coloration and

markings to perfection. The shell is fusiform, arcuate, much attenuate at the base, spire elevated, thirteen-whorled, of which three are apical, glassy, smooth, the rest beautifully turned and cancellated below the sutures, the last whorl is acutely angled at the periphery, pale straw in colour, flecked and lined with white at the periphery, which is also decorated with a row of reddish spots. At the median band, and likewise at the base, there are also white blotches, and the whole surface of the last whorl is closely transversely sulculose, the sulci being dotted. All are unfortunately more or less broken at the edge of the outer lip.

(*saecularis*, in allusion to the "*annus saecularis*," year of Jubilee, 1897, in which this exquisite cone was discovered.)

PLEUROTOMA (DRILLIA) ANGRIASENSIS, *sp. nov.*

(Pl. 1, f. 3.)

P. testa fusiformi, solidiuscula, laevi, nitida, anfractibus decem, longitudinaliter costatis, costis in medium rugulosis, in ultimo ferè evanidis, ultimo anfractu latiore, apud basim subtruncato, apertura ovata, labro exteriore effuso, paullum incrassato, sinu inconspicuo.

Long. 20, lat. 7·50 mill.

Hab. Angrias Bank, W. of Bombay (Capt. Tindall).

A white, smooth Drillia, with nodulous angled whorls, and almost plain last whorl, lip effuse, base subtruncate. This more resembles *Drillia cygnea* Melv. and Standen from Lifu than any other species known to me.

PLEUROTOMA (DRILLIA) RESPLENDENS, *sp. nov.*

(Pl. 2, f. 8.)

P. testa fusiformi, solida, nitida, perlaevi, ad apicem mammillata, vitrea, anfractibus decem, incluso apicali, ad suturas compressis, rubro-stramineis, longitudinaliter costatis,

costis incrassatis, perlævibus, pallidé stramineis, interstitiis lævissimis, rubrotinctis, ultimo anfractu apud basim paullum truncato, ad medium longitudinaliter, sicut suprá, costato, infrá ad basim lævisimo, albescente, apertura ovata, labro incrassato, sinu suturali profundo, excavato, dorsaliter leniter bifasciato, margine columellari recto.

Long. 19 mm., lat. 5.

Hab. On the Oceanic cable, near the entrance to the Persian Gulf.

A very shining, smooth, brightly-coloured *Drillia*, with about ten whorls, the apical mammillate, vitreous, the rest shining, ornamented with pale straw-coloured thickened ribs on a smooth blood-red ground, the last whorl smooth below the middle to the base, where it is almost white. Above, the ribs are as in the upper whorls, the mouth is oval, outer lip somewhat thickened, sutural sinus profound, excavate, dorsally the outer lip is slightly bifasciate, the columellar margin is straight.

A few specimens, all alike, save as to size.

CYTHARA HYPERCALLES, *sp. nov.*

(Pl. 1, f. 5.)

C. testa eleganter fusiformi, versus apicem attenuata, gradatula, solidiuscula, anfractibus, inclusis duobus apicalibus, vitreis, decem, longitudinaliter costatis, costis inæqualibus, transversim spiraliter undique arctissimé striatis, stramineo-ochraceis, dorsaliter et præcipue circá suturas brunneo-suffusis vel maculatis, ultimo anfractu apud basim paullulum recurvo, apertura angusta, oblonga, labro extus incrassato, albo, dorsaliter binis maculis brunneo-rufis decorato, intus simul ac margine columellari, minuté denticulato.

Long. *spec. max.* 15, lat. 5 mm.

Hab. Muscat in 20 fathoms ; sandy mud.

Six examples, but only three mature, of an elegantly formed *Cythara*, fusiform, gradate, ten-whorled, two being

apical and glassy, the rest unequally longitudinally ribbed, and spirally closely striated, pale straw colour, dorsally marked with darker red-brown effusion, and often spotted below the sutures. The lip is thickened, white, being within, as on the columellar margin, minutely denticled. There are two brown spots at the back of the outer lip.

(*ὑπερκάλλης*, surpassingly beautiful).

CLATHURELLA FORAMINATA Reeve *var*: CAMACINA, *nov.*

(Pl. 1, f. 15.)

C. testa fusiformi brunneo-rufa, solidula, anfractibus septem vel octo, quorum apicali minimo, lævi, brunneo-nigro, cæteris arctissimé et pulchré clathratis, apud suturas impressis, ventricosulis, clathris squarrosis junctura gemmulatis, apertura ovata, aurita, intus rufa, labro incrassato pulchré crenulato, sinu lato, haud profundo, columella feré recta.

Long. 9, lat. 2·75 *sp. maj.*

Hab. Karachi, and Linjah.

A very neat form, of the same alliance as *C. violacea* Pease, or *clandestina* Desh. The three specimens before us are alike in shape, two are dark-brown in colour, the third a paler ochre yellow. The clathrations are beautifully regular, and in a young specimen the point of junction between the longitudinal and spiral liræ is gemmuled with shining small papillæ. The whorls are seven or eight, aperture acute, outer lip thickened, crenulated sinus wide, but not cut deeply, columella nearly straight.

Although half as long again (9 as against 6 mm.) as any of the typical *foraminata* Rve, that have been collected at Karachi (Townsend), or Bombay (Blanford, Abercrombie, etc.) where it seems to be abundant, a closer investigation convinces me it is not specifically distinct. I have, nevertheless, drawn up a full description, and it may be observed that a few points of distinction, in

addition to that of size, occur. For instance, the canal is shorter, aperture wider, with the surface of the whorls more coarsely, though equally evenly, clathrate.

(κὰμαξ, a trellis. Lat. *clathrus.*)

LACHESIS BICOLOR, *sp. nov.*

(Pl. 1, f. 17.)

L. testa fusiformi, solidiuscula, versus apicem attenuata, carneo-brunnea, ad utramque extremitatem albescente, anfractibus fortasse octo—apicalibus?—cateris longitudinaliter flexuoso-costulatis, costis spiraliter arcté striatis, apertura laté ovata, labro effuso, simplici, haud sinuigero.

Long. 7, lat. 2 mm.

Hab. Persian Gulf.

Several species of the small genus, *Lachesis*, inhabit the Mediterranean, one of them being British. One Japanese species is recorded, and one from St. Paul I., South Indian Ocean (*L. Turqueti* Velain.). It is interesting, therefore, to find another in the Persian Gulf, possessing the family "facies," but the outer lip more effuse than usual, the colour pinkish-brown, whitening towards both extremities, the shape fusiform, probably eight-whorled, but the apical whorls are wanting in the specimen before us.

ANCILLA TINDALLI, *sp. nov.*

(Pl. 1, f. 1.)

A. testa oblongo-fusiformi, apud apicem attenuata, nitidissima, pallide stramineo-ochracea, anfractibus septemocto quorum tribus apicalibus, pellucido-vitreis, cæteris transversim paullum infrá suturas unisulcatis, interstitiâ castaneo-affusa, ultimo anfracta vix effuso, in medio cinnamomeo-castaneo ochraceo, delicate sub lente lineolato, juxta basim fasciola pallide castanea decorato, apertura ovato-

oblonga, intus albida, labro extus vix effuso, margine columellari paullum calloso, nitidissimo.

Long. 17, lat 8 mm.

Hab. Angrias Bank, Lat. 16·50, long. 72. (Captain Tindall).

A very elegant, shining, cinnamon-coloured shell, banded below the sutures and towards the base of the last whorl with chestnut brown. Allied to *A. marginata*, but of different shape, and much smaller.

Ten specimens. We have pleasure in connecting with this *Ancilla* the name of Captain Tindall, of the S.S. "Patrick Stewart," who, at the request of Mr. Townsend, took a few soundings off the Angrias Bank, and some other places on the Malabar Coast.

MARGINELLA (GLABELLA) QUILONICA, *sp. nov.*

(Pl. 1, f. 4)

M. testa politissima, nitida, perlævi, ovata, spira pyramidali, anfractibus quinque, ventricosulis, albocinereis, supra suturas spiraliter rufozonatis, ultimo anfractu apud medium et infra bizonato, apertura angusta, labro exteriore incrassato, albido, intus multidenticulato, margine columellari fortiter quadriplicata.

Long. 8, lat. 4 mm.

Hab. Quilon, Malabar Coast, at 15 fathoms (Captain Tindall).

Four or five examples of a pretty shining polished shell, having the same disposition of banding as the smaller *M. suavis* (Souverbie), from New Caledonia. The whorls are five, cinereous white, banded once, spirally, just above the sutures, with a rufous-brown zone, the last whorl being bizoned, below the lower zone the basal region is white, shining, the aperture narrow, the outer lip thickened, within denticled, columella strongly four-plaited.

We carefully compared the shell with the description and figure of *M. deformis* Nevill, from Ceylon, the marking being similar, but form entirely different.

With a few other interesting Mollusca, this was dredged by Captain Tindall, during a cruise of the S.S. "Patrick Stewart," in 1896, off the Malabar Coast and West of Ceylon. We may add that some of the specimens were encrusted with a coral (*Heteropsammia sp.**)

MARGINELLA (PERSICULA) OODES, *sp. nov.*

(Pl. 1, f. 16.)

M. testa minuta, crassiuscula, perlævi, albida, nitida, spira omninó immersa, anfractu ultimo globoso, apertura oblonga, angusta, labro percrasso, nitido, lævi, intus planato, non denticulato, columella quadriplicata.

Long. 2, lat. 1·25 mm. (*sp. maj.*).

Hab. Bushire (Persian Gulf).

About a dozen examples of a little pure-white shining *Cypræa*-like shell, globose, with spire wholly immersed, the mouth narrow, oblong, the outer lip very thickened, quite smooth and not denticulate within. Columella four-plaited. From Issel's description of his *M. pygmæa*, which must be near this species, the colour is yellowish, and the outer lip is denticulate within. From the figure we would gather the mouth was narrower than in our species, and the form more oblong than globose. Issel described it from one example only, found in the Gulf of Suez, and what purports to be it has also been once recorded from the Persian Gulf. It is very likely this nearly allied species.

(ὠώδης, egg-shaped.)

FUSUS ARABICUS, *sp. nov.*

(Pl. 1, f. 6.)

F. testa parva, attenuata, lanceolata, gracili, anfractibus novem, duobus apicalibus brunneis omninó lævibus,

* These were kindly examined by Prof. S. J. Hickson, F.R.S.

cæteris ventricosulis, apud suturas astrictis, longitudinaliter costatis, penultimo et ultimo ad octo costis, rotundatis, incrassatis, spiraliter undique arcté costulatis, interstitiis spiraliter granuloso-liratis, ultimo rectirostrato, canali longa, apertura ovata, labro vix incrassato, intus spiraliter plicato, columella septemplicata.

Long. 34, lat. 10·50 mm. *spec. maj.*

Hab. Muscat, Arabia, 15 fathoms mud and sand.

A small species, but one that has attained its full growth, being a typical *Fusus* in form, attenuately lanceolate, nine-whorled, two of them are apical, smooth, brown, the rest constricted at the sutures, ventricose, longitudinally thickly ribbed, ribs about eight on the two last whorls, these ribs are spirally crossed by revolving riblets, or raised lines, the interstices being granuloso-lirate, the colour is cinnamon brown, slightly darker on the ribs, the mouth is ovate, canal straight, prolonged, lip within plicately striate, the columella is seven plaited, these plaits are the continuation of the spiral riblets.

Two species, similar, but one slightly smaller than the other, say long. 32, lat. 9·50. Also three or four, in young condition, have been subsequently (1898) procured from the same locality.

BULLIA CEROPLASTA, *sp. nov.*

(Pl. 2, f. 13.)

B. testa parva, fusiformi, tenui, cerea, paullum nitente, lævissima, anfractibus septem, quorum duobus apicalibus, perlævibus, mammillatis, cæteris longitudinaliter costulatis, costis rectis, ultimo anfractu cæteros longitudine exæquante, costis infrà medium evanidis, ad basim spiraliter multi-sulcatis, sulculis profundis, basi subtruncata, apertura ovata, labro paullum effuso, parum incrassato.

Long. 12, lat. 4·50 mm.

Hab. Mekran Coast.

A thin, waxy little Bullia, with a superficial resemblance to certain Nassæ, e.g., *N. teretiuscula* Ad., and *pulchella* Ad. Very smooth, slightly shining, cinereous drab in colour, seven whorled, two being apical, swollen, vitreous, the rest all longitudinally ribbed, the ribs very smooth, as are the interstices, the last whorl about equals the remainder put together, here the ribs disappear below the middle of the whorl, and in their place are several spiral deeply sulcate lines around the base of the shell. The aperture is oval, outer lip a little effuse.

Ten or twelve specimens.

(κηρύπλαστος, waxen.)

BULLIA (PSEUDOSTROMBUS) INDUSICA, *sp. nov.*

(Pl. 1, f. 19.)

B. testa ovato-fusiformi, spira acuminata, paullum nitida, pallidissimé straminea vel albo-cinerea, anfractibus octo (incluso apicali vitreo, lævi) ad suturas impressis, ventricosulis, tribus supernis plus minusve lævibus, nitidis, cæteris undique spiraliter lineari-sulcatis, infrá, juxtá suturas bino plicarum ordine transverso, nequaquam granoso nec decussato incrassatis, ultimo ventricoso, costulis spiralibus magis prominulis ad basim, apertura ovata, intus alba, labro paullum effuso, tenui, canali brevi, columella paullum excavata, operculo corneo, ovato, margine serrato, nucleo apicali.

Long. 23, lat. 10 mm.

Hab. Karachi.

This cannot be confounded with *B. lineolata* (= *Belangeri* Kien), there being no trace of fulvous marking, nor is the shell of the same consistency, being far more delicate. The transverse sulculi, too, in *B. lineolata*, are only partial over the whorls, leaving a considerable space below the sutures smooth, with the exception of a once folded sutural plait. The species before us is ovately fusiform

with acuminate spire, somewhat shining, very pale straw colour or whitish grey, whorls eight, the first three being smooth, the rest regularly spirally line-furrowed, the sutures are impressed, and the sutural plaits are shown by a double row of thickened spiral costulæ, there is no sign of decussation or granulosity, the aperture is ovate, outer lip slightly effuse, thin, canal short, columellar slightly excavate. The operculum, which is present in both specimens examined, is horny brown, ovate, with serrated margin, and apical nucleus. (Karachi is at the mouth of the R. Indus, hence the trivial name.)

MUREX (OCINEBRA) FLEXIROSTRIS, *sp. nov.*

(Pl. 1, f. 11.)

M. testa fusiformi, utrimque acuminata, brunnea, asperrima, spira turrita, anfractibus septem, apicalibus duobus lævibus, cæteris vix varicosis, squamosis, longitudinaliter crassicostatis, angulatis, spiraliter liris squamiferis accinctis, anfractu ultimo ad basim attenuato, canali longa, flexirostri, apertura rotundo-ovata, labro fimbriato, dorsaliter, juxta labrum, varicifero, columella et interiore pallidé violacea.

Long. 8, lat. 4 mm.

Hab. Muscat, 10 fathoms, coral sand.

A distinct little *Ocinebra*, being, in the most perfect of the specimens, which is selected for the type, of a brown colour, acuminate both posteriorly and anteriorly, rough with small scales on the liræ which cross the thickened, obliquely-angled ribs spirally, the last whorl attenuate towards the base with a long (2·50 mm.) beak, bent backwards, the aperture is roundish, columella and interior of the mouth pale violet, outer lip fimbriate, and with one large varix just behind it. The shell is otherwise singularly free from varices.

A smaller example, which has not attained its full

growth, is even darker brown, with the same pale violaceous interior. Three or four specimens.

(*flexirostris*, curvedly beaked.)

CERITHIOPSIS (SEILA) HINDUORUM, *sp. nov.*

C. testa cylindracea, multum attenuata, solidiuscula, castanea, anfractibus quin- vel se-decim, undique spiraliter tricarinatis, carinis arctis, lævibus, æqualibus, interstitiis longitudinaliter liratis, ultimo anfractu quinque-carinato, juxta basim angulato, basi excavata, apertura subquadrata, labro simplici, canali brevissimo, subretuso.

Long. 13, lat. 4·50 mm.

An abundant shell at Karachi, especially the neighbourhood of Manora. We have seen nearly a hundred specimens, differing a little in basal breadth, and length, and also in number of whorls, the colour varying from pale chestnut to dark russet; and the larger examples are longitudinally streaked or suffused with darker brown. *Seila bandorensis* Melv., described from Bombay examples, occurs with it, and we shall hope in a succeeding paper to draw up a revised description of this, Mr. Townsend's specimens being dredged, and perfect at the mouth.

S. hinduorum is no doubt near *dextroversa* Ad. and Reeve, but the spiral carinæ are all equal, and the colour is chestnut brown. A strong family resemblance characterises this section of Cerithiopsis, the majority of species being American.

SCALARIA MALCOLMENSIS, *sp. nov.*

*S. testa ovato-fusiformi, delicatula, tenui, albo-lactea, turrita, anfractibus octo vel novem, apicalibus * * *, undique arcté obliqui-costatis, costis lamellosis, incurvis, papyraceis, longitudinaliter connatis, auritis, suturas superimpendentibus, lamellis simul ac interstitiis transversim leniter*

striatis, apertura rotunda, peristomate extus circiter lamelloso, rotundo.

Long, 9, lat. 4 mm.

Hab. Malcolm Inlet, Persian Gulf; 25 fathoms.

Allied to the Mediterranean *S. muricata* Risso, but the lamellæ are closer, more ear-shaped at the sutures, and thinner in substance. They are likewise longitudinally continuous and connate along all the whorls. This new form is a remarkably graceful species. Two examples occurred.

EULIMELLA KAISENSIS, *sp. nov.*

E. testa perlonga, multum attenuata, polita, nitida, albolactea, anfractibus duodecim, apicali vitreo, pellucido, heterostropho, anticé verso, omnino lacteis, apud suturas impressis, ventricosulis, infrá, juxta suturas, vitta semipellucente spiraliter succinctis, aliter albolacteis, apertura ovatorotunda, labro extus vix incrassato.

Long. 6, lat. 1 mm.

Hab. Kais (or Gais) Island, Persian Gulf, 10 fathoms.

A very prolonged, shining, milky white, perfectly smooth shell, twelve whorled, with heterostrophe apex, glassy, coiled on the front of the next whorl, the whorls are impressed at the sutures, and slightly ventricose.

MIRALDA OPEPHORA, *sp. nov.*

M. testa attenuato-fusiformi, minuta, albida, subcrystallina, anfractibus octo, apud suturas multum impressis, ventricosulis, longitudinaliter arcticostatis et spiraliter carinatis, superné tribus, ultimo anfractu quatuor carinis instructo, interstitiis profundis, quadratis, decussatis, ultimo anfractu ad basim infrá carinam delicaté spiraliter tornato, apertura oblonga, labro tenui, simplici, columella inconspicué uniplicata.

Long. 4, lat. 1·50 mm.

Hab. Karachi (E. R. Shopland and F. W. Townsend).

A beautifully chased little species; allied to certain *Odostomiæ* with decussated sculpture, and I follow Tryon in including such under the subgeneric—or generic—name of *Miralda*. It is a semicrystalline little shell, white, alternately sculptured with many longitudinal ribs, crossed by prominent keels, three in the upper whorls, four in the lowest. The interstices are quadrate, and deep. Below the lowest keel on the last whorl, the base is delicately spirally striate. The mouth is oblong, outer lip simple. The columella is once plaited but this is not very conspicuous. Three or four specimens.

(ὀπηφόρος, chink bearing, from the deep quadrate interstices.)

TURBONILLA BASILICA, *sp. nov.*

T. testa minuta ad apicem perattenuata, crystallina, tenui, anfractibus novem vel decem, quorum apicali heterostropho, vitreo, lævi, cæteris apud suturas multum appressis, ventricoso-tumidis, longitudinaliter obtusi-costatis, costis flexuosis, obliquis, apertura ovata, labro tenui, simplici, columella recta.

Long. 4, lat. 1·25 mm.

Hab. Persian Gulf, off anchor, Bunder-Abbas.

An exceedingly delicate, glassy nine or ten-whorled *Turbonilla*, with very impressed sutures, and tumid whorls, the longitudinal ribs being somewhat flexuose. Mouth and outer lip simple, columella straight. Judging from the figure, it comes near *T. acuticostata* Jeffreys, from the Mediterranean, but a more delicate species, of about the same size. The longitudinal ribs of the last whorl, though terminated just above the base, which is smooth, do not seem to have the spiral line at the point of termination, as in *acuticostata*. Three examples.

(*basilicus*, kingly.)

TURBONILLA (PYRGOSTELIS) MANORÆ, *sp. nov.*

T. testa oblonga, fusiformi, delicatula, semipellucida, albida, apice heterostropho, vitreo, lævi, anfractibus octo, ad suturas impressis, ventricosulis, undique recticostatis, costis lævibus, interstitiis spiraliter filostriatis, apertura rotundo-ovata, labro tenui, simplici, paullum effuso, columella rectiuscula.

Long. 4, lat. 1·50 mm.

Hab. Manora, Karachi.

Several examples of a *Turbonilla*, which, did it but possess the columellar plait, so characteristic a feature in the *Pyrgulinæ*, would be easily comparable with *P. Edgarii* Melv., or *P. interstriata* Souv. It is eight whorled, white, delicate, longitudinally straightly ribbed, ribs smooth, interstices spirally filostriate, mouth roundly ovate, outer lip slightly effuse, simple, columella straight. Allied to *T.* (*Pyrgostelis*) *flexuosa* Jeffreys, from the Mediterranean, and the recently described *T.* (*Pyrgostelis*) *Emiliæ* Melv., from Bombay; it is much larger than this latter species, whorls more ventricose, and eight, as against six whorled.

TURBONILLA (PYRGOSTELIS) TEMPLARIS, *sp. nov.*

T. testa crystallina, alba, delicata, turrita, gradatula, anfractibus decem, quorum apicali vitreo, lævi, bulboso, cæteris gradatis, lævibus, longitudinaliter recticostulatis, interstitiis omnino lævissimis, ultimo anfractu costulis infra medium evanidis, ad basim lævi, apertura ovata, labro tenui, simplici, columella obscurissimè uniplicata.

Long. 4·50, lat. 1·25 mm.

Hab. Karachi and Mekran Coast (Townsend and Shopland).

An exceedingly pretty species, the whorls are white, ten in number, including the glassy, bulbous apical, the rest being scalariform, proportionately graduate, and taper-

ing, crystalline and delicate. Longitudinal straight riblets adorn each whorl, these, as in the case of so many ribbed *Turbonillæ*, are evanescent below the middle of the last whorl. The aperture is ovate, outer lip thin, elongate, columella very obscurely once plaited. This shell has for its allies *T. scalaris* Phil., a European species, entirely different in texture and substance, though akin in form, and *T.* (*Pyrgostelis*) *Velaini* Tryon = *scalaris* Velain *non* Mont, from the Island of S. Paul, South Indian Ocean. I have only seen a figure and description of this latter species, from which *T. templaris* seems to differ in the perfect smoothness of the interstices between the ribs, those in *T. Velaini* being striate, in the ten as against eight whorls, and in being larger in all its parts. *T. Abercrombiei*, described by myself in 1893, from Bombay, is like in its graduate whorls, but differing in form of mouth and last whorl, and lastly, *Pyrgulina pyrgomella* Melv., also from Bombay, resembles our shell in form, but here the longitudinal ribs begin at a little distance from the sutures, the intermediate space being smooth, and the ribs are also slightly papillose at the upper end. The columella is also very conspicuously plaited.

(vide *Proc. Mal. Soc.*, Vol. II., 1896, pp. 113, 114.)

(*templaris*, of or belonging to a temple.)

NERITA (HEMINERITA) ANODONTA, *sp. nov.*

N. testa parva, subglobosa, solidiuscula, anfractibus tribus, apicalibus erosis, ultimo rapide accrescente, spiraliter filo-lirato, in uno specimine liris concinné nigris, regularibus, in altero irregulariter dispositis, hic illic nigro-tessellatis vel maculatis, apertura lunata, labro paullum incrassato, intus lævi, area columellari planata, nitida, ochraceotincta, margine non denticulato, recto, operculo paucispirali, extus granuloso.

Alt. 9, diam. 10 mm.

Hab. Karachi (J. O. Twells, Esq.).

A small, but well-marked species, for the sight of which I am indebted to Mr. G. B. Sowerby. It belongs to the toothless section of *Nerita* proper, and is really best distinguished from certain *Neritinæ* by its operculum. It is variable in its painting: one of the examples before us is neatly spirally threaded, the liræ being black, another is more irregularly lirate, and tesselated, here and there only, with black. The mouth is, as just observed, not denticulate, nor has the outer lip teeth within the aperture. The operculum is paucispiral, granulated without.

(ἀνόδους, without teeth.)

TROCHUS (INFUNDIBULUM) FULTONI, *sp. nov.*

(Pl. 1, f. 21.)

T. testa profundé pseud-umbilicata, solidula, pyramidata, conica, anfractibus septem vel octo, apicali subacuto, interdum feré rectis, interdum suprâ suturas tumidulis, quasi gradatulis, vividé viridi-coloratis, et radiatim longitudinaliter rubro varii-pictis, flammis superné in omnibus speciminibus haud variantibus, infra, in ultimo anfractu nunc condensatis, nunc tenuibus, vel fulgetrinis, anfractibus omnibus undique spiraliter liris granulosis instructis, superné quatuor vel quinque ordinibus lirarum, ultimo quinque vel sex, ad peripheriam angulato, basi subplanato, viridi, et delicaté rubripicta, lirarum quinque ordinibus prædita, interdum granulis evanidis, interdum, et sæpius, distincté granulosis, striis concentricis interstitialibus, apertura quadrata, intus iridescente, crassilirata, labro exteriore crassiusculo, columella iridescente, plicata, margine vix crenato, basi intus crenulato. Operculo corneo, cartiligineo, multispirali.

Alt. 25, *sp. maj.*, diam. 25 mm.

Hab. Entrance to Persian Gulf (G. of Oman).

A great many specimens, all nearly similar, but with a slight tendency to vary in granulosity of spiral liræ, and also, in some instances, in tumidity of the lower part of the central whorls.

Hitherto this shell must have been mixed up with *T. radiatus* Gmelin, from which, however, we can always distinguish it. Some points of difference consist in the apex never being orange tinted, the whorls uniform and more vivid green, the interstitial liræ between the granular striations being absent in all the specimens examined, the diametric measurement less in proportion to the altitude than in either *T. radiatus* Gmel., or *T. vividus* Reeve (the nearest approach to our species) and the false umbilicus more profound, and narrower. The general form is likewise more acutely narrowly conical.

Mr. Hugh Fulton has rendered me most valuable assistance in the elucidation of this and other critical species in Mr. Townsend's and Commander Shopland's* collections; and it gives me much pleasure to connect this interesting species with his name.

CALLIOSTOMA DURICASTELLUM, *sp. nov.*

(Pl. 1, f. 14.)

C. testa perforata, pyramidato-conica, pallide rufo-ochracea, solida, elegante, anfractibus octo, haud prominulis apud suturas, undique spiraliter arcté et delicaté punctosulcatis, infra, juxta suturas, et ultimo apud peripheriam spiraliter bifuniculato, squarrosé rufotessellato, in medio interdum unicolore, interdum obliqué rubrisparso et maculato, ultimo ad peripheriam acutangulato, basi concinné spiraliter sulculosa, hic illic rubri-picta, apertura obliqué quadrata, intus iridescente, labro extus tenui, simplici.

Alt. 10, diam. 7·50 mm.

Hab. Batticaloa, Ceylon (Captain Tindall).

A pretty Trochoid shell, allied to *C. polychroma* Ad., *C. interruptum* Wood, and others of that section of the genus. The shell is perforate, pyramidal, the whorls close set, and not prominent at the sutures, the spiral puncto-

* c.f. *Ann. & Mag. N. H.*, Ser. 7, Vol. I., (1898) p. 194 sqq.

striation or sulcation is uniform, and close. At the bottom of each whorl, just above the sutures, the sulci are broader and funiculate, and tessellated with red, the remainder of the surface is sometimes flushed with red, and sometimes quite plain.

A good many examples, all alike in form, but differing slightly in pattern, as described above.

(*duricastellum*, a stronghold.)

OSTREA TOWNSENDI, *sp. nov.*

(Pl. 2, f. 14.)

O. testa suborbiculari, albida, dorsaliter rufo-suffusa, probabiliter per lobos valvæ inferioris adhærente, valva superiore multiplicata, costis ramosis, apud medium, præcipué dorsaliter, elevata, superficie delicate longitudinaliter sericata, marginem ad ventralem lamellata plicis albidis, quindecim ad septemdecim, divaricatis, plicis variis, acuté angulatis, cardine magno, superficie interna albo-ochracea.

Alt. 2·75, lat. 3 unc.

Hab. On the Telegraph Cable, entrance to Persian Gulf.

A few specimens, which, when cleared of nullipores and other growths, present a beautiful shell surface. We could almost give it the palm in a genus which, uncouth as are many of its members, yet in some few instances almost rivals the *Spondyli*. The present species which, rightly, is to bear the name of its discoverer, Mr. F. W. Townsend, is suborbicular in shape, white, many plaited round the ventral margin, the plaits being acute-angled. Transverse lamellæ are seen above the plaits, the rest of the surface being beautifully longitudinally sericeous and shagreened; dorsally there is a suffusion of red-brown, the depressions between the branching ribs being darker. The hinge is large, inner surface yellowish white.

PLICATULA PERNULA, *sp. nov.*

(Pl. 2, f. 10.)

P. testa paullum inæquivalvi, inæquilaterali, pediformi, parva, depresso-planata, pallidé carneo-rufa, costis obliquis circiter decem decorata, his costis hic illic spiniferis, spinis brevibus, tubiferis, squamatis, transversim superficie omni valvarum rudi-corrugatis, umbonibus angustis, latere antico arcuato, ventrali, cum postico, leniter rotundato-oblongo, intus, in speciminibus maturis circiter marginem incrassato, longitudinaliter costarum impressiones exhibente, cardine utroque dentibus duobus deviis.

Alt. 20, lat. 15, diam. 4 mm., *sp. maj.*

Hab. Malcolm Inlet, Persian Gulf; 24 fathoms, mud.

Apparently near *P. depressa* Lam., from the New World, and *P. muricata* A. Ad. Mr. Hugh Fulton, who has made comparisons with this latter, writes me that that shell is not so narrow at the umbones, and that the plications are far more numerous, nor are the spiny scales tubulous as in *P. pernula.*

Though small, it appears full grown: the shells are covered with *Serpulæ* and *Lepraliæ*; eight examples in all.

(*pernula*, a little ham, from the form.)

LIMA (LIMATULA) LEPTOCARYA, *sp. nov.*

(Pl. 2, f. 2.)

L. testa tenui albida, recta, æquivalvi, oblonga, clausa, ventricosa, longitudinaliter arcté costulata, costis ad medium valvarum prominulis, ad latera evanescentibus, numero ad sex et viginti, umbonibus distantibus, sulculo mediano vix notato, auriculis æqualibus, margine cardinali lato.

Alt. 8, long. 5, diam. 4·50 mm.

Hab. Muscat; 10 fathoms.

Resembling the British *L. subauriculata* Mont., and especially *L. elliptica* Jeffr. In the former species the longitudinal median sulcus is distinct and central, in the

latter it is inclined to one side. In this new form, the median sulcus is hardly perceptible. As in *L. elliptica*, the longitudinal riblets are evanescent at the sides, being about twenty-six in number; these riblets are more pronounced than in that species. Several examples.

(λεπτοκάρυον, a light nut, the fruit of the hickory, from the shape of the shell.)

YOLDIA CLARA, *sp. nov.*

(Pl. 2, f. 7.)

Y. testa crystallina, pellucide tenui, æquivalvi, inæquilaterali, umbonibus parvis, approximatis, margine dorsali utrimque leniter declivi, anticé oblongo-ovato, margine ventrali convexiusculo, posticé paullum producto, dentibus pectinatis, in utraque valva posticé quatuordecim, antice eodem numero, superficie nitidissima, vitrea, concentrice obliquilirata, liris indistinctis.

Alt. 8, lat. 15, diam. 4·50 mm.

Hab. Bushire, Persia, 4 fathoms, mud.

A very delicate crystalline pellucid *Yoldia*, the superficies concentrically obliquely lirate, and slightly prismatic, the shell is posteriorly produced, anteriorly ovate-oblong, the ventral margin somewhat convex, the umbones small, approximate, dorsally declining on each side; teeth, pectinate, about fourteen in either valve on each side of the umbones.

The only species nearly allied to this is *Y. serotina* Hinds, which is also in the Townsendian collection, having been found among shell-growth on the Telegraph Cable at 55 fathoms mud, in lat. 25°58′ N. and long. 57°3′ E. This is not so transparent a shell, and posteriorly not quite so produced, the concentric liræ in *Y. serotina* are clearer cut, and the umbones more prominent, causing the dorsal margin anteriorly to be slightly arcuate.

(*clarus*, clear, transparent.)

MYTILICARDIA FFINCHI, *sp. nov.*

(Pl. 2, f. 17.)

M. testa oblongo-trapezoide, inæquilaterali, rufo-gilva, umbonibus incurvis, margine dorsali posticé recta, anticé excavato-declivi, latere postico recto, ventrali ad anticum oblique declivi, antico breviter oblongo, lunula parva, profundé cardiiformi, testa longitudinaliter quatuor-decim vel quindecim costis decorata, anticé angustis, irregulariter nodosis, posticé majoribus et latioribus, sæpe spiniferosquamosis, squamis foliaceis, cochlearibus, præcipue latus apud posticum conspicuis, simul ac ad posticam marginis dorsalis partem, intus albida.

Alt. 25, *sp. maj.*, lat. 37 mm.

Hab. Muscat, 10 fathoms coral sand, and Persian Gulf, 33 fathoms.

Seven or eight examples varying only in size, being very uniform in shape and structure. We have taken the largest specimen as our type. This new *Mytilicardia* is an interesting and conspicuous shell, coming in the same category as *M. calyculata* L., from the Mediterranean, than which it is much broader, and *M. crassicostata* Lam., a more elaborate species altogether.

It is of a fulvous-dun colour, the umbones incurved, placed very far forward, the ventral margin is posteriorly almost straight, anteriorly excavate, the posterior margin also straight, anterior shortly oblong; the ventral obliquely tending from the posterior to the anterior margin. The longitudinal ribs are fourteen to fifteen in number, the posterior much the larger and wider, and are ornamented, the smaller with nodules, the larger with spiny, foliaceous and spoon-shaped squamæ.

Named, at the request of Mr. Townsend, in honour of his chief, Mr. B. T. Ffinch, C.I.E., who is taking considerable interest in the results of these numerous dredging expeditions in the Arabian Sea and Persian Gulf.

BASTEROTIA ARCULA, *sp. nov.*

(Pl. 2, f. 16.)

B. testa æquivalvi, inæquilaterali, subquadrata, inflata, valvis parum hiulcis, umbonibus incurvis, prominulis, margine dorsali utrimque recto, antico rotundato-truncato, postico obliqué producto, ab umbonibus usque ad marginem ventralem posteriorem carinato et acutangulato, cardine in utraque valva uno dente instructo, dentibus productis, magnis, superficie sordidé alba, granulosa, latere postico cordiformi, plano-marginato, minuté granuloso, intus alba.

Alt. 8, lat. 13, diam. 7·50 mm. *sp. maj.*

Hab. Karachi, 3 fathoms, mud and sand.

This genus, formerly known as *Eucharis* Recluz *non* Latreille, bears, until the hinge with its conspicuous teeth, one in each valve, be examined, a considerable resemblance to certain members of the family *Arcadæ*. The new species now before us, especially so; indeed, it might be considered a small variety of *Arca tetragona* L.

The shell is equivalve, inequilateral, squarrose, inflated, the valves hardly gaping laterally, the umbones incurved, prominent, the dorsal margin straight on both sides of the umbones, anteriorly the shell is roundly truncate, posteriorly obliquely produced, from the umbones to the posterior end of the ventral margin runs an acutely angled keel, the surface of the shell is dirty white, granulose, the posterior side flattened, plane margined (with the keels just mentioned), heart shaped, minutely granular. Within the shell is white.

One perfect shell, and a larger half valve.

(*arcula*, a little ark or chest.)

CIRCE NANA, *sp. nov.*

(Pl. 2, f. 9.)

C. testa parva, obliqué orbiculari, solidiuscula, umbonibus paullum attenuatis, prominulis, anticé ovata, postice obtusangulo-truncatula, margine ventrali convexiusculo, dorsaliter

posticé feré recto, anticé multum declivi, superficè albida concentrice irregulariter lirata, liris apud medium anticé et posticé oblique granuloso-undosis, intus alba, linea palliali parum sinuosa.

Alt. 7, lat 8·50 mm.

Hab. Indian Ocean ; 33 fathoms, long. 26°10′ N., lat. 52°50′ E., mud, and coral rock.

A dwarf *Circe*, in size resembling the British and Mediterranean *C. minima* L. It is white, obliquely orbicular, the umbones slightly attenuate, prominent, the dorsal margin straightish posteriorly, much declining anteriorly, the shell being unequally concentrically lirated, the liræ ornamented with oblique nodules tending regularly posteriorly and anteriorly, ceasing beyond the middle, while the shell is slightly shining. Within white, the pallial line hardly sinuous.

DIPLODONTA GENETHLIA, *sp. nov.*

(Pl. 2, f. 11).

D. testa oblique rotunda, ventricosa, nitida, lævi, indistinctè concentricé striata, straminea vel cinereo-alba, umbonibus approximatis, incurvis, prominulis, dorsaliter utrimque rapidé declivi, posticé rotunda, anticé à medio marginem ad ventralem tri- vel quadri-plicata, plicis obtusis, inconspicuis, intus albescente, cardine in utraque valva bidentato, dentibus inæqualibus.

Alt. 7, lat. 7·50, diam. 5 mm.

Hab. Gais (or Kais) Island, 7 to 10 fathoms ; also Muscat, 10 fathoms, Persian Gulf.

An obliquely rounded shell, straw coloured or olivaceous or ashy white, shining, concentrically striate, umbones approximate, prominent, valves extremely ventricose and tumid, posteriorly round, anteriorly three- or four-plaited, the plaits commencing below the centre of the shell to the ventral margin.

A great many examples from the two above-mentioned localities.

(γενέθλιος, generative, from its frequency.)

GARI ERASMIA, *sp. nov.*

(Pl. 2, f. 3.)

G. testa parva, oblonga, æquivalvi, feré æquilaterali, valvis dorsaliter leniter declivibus, anticé oblongis, sicut in latere postico, margine ventrali longo, convexiusculo, feré recto, superficie violacea vel roseo-ochracea, arctissimé concentricé costulata, interstitiis posticé fere lævibus, à medio feré ad latus anticum alveariibus, costulis crenelliferis, anticé crassigranulosis et undulosis, bis alternatim dispositis, quadratulis, intus parum nitente, violacea vel rosea.

Alt. 5, long. 9, diam. 3 mm., *sp. maj.*

Hab. Gais (or Kais) Island; 14 fathoms, broken rock and coral sand.

One of the smallest, if not the least, of the genus, but none the less beautiful. Two specimens are before us. Of these, the larger, pale violet in colour, is of an oblong shape, rounded off anteriorly and posteriorly, slightly convex, but running almost straight at the ventral margin. The ornamentation is peculiar. Closely concentrically costulate, these ribs posteriorly are almost smooth, as are the interstices, towards the middle of each valve the costæ become crenelliferous, the interstices honeycombed, and, at the anterior margin, they are noduled and granuled, in an alternate manner, assuming a diamond pattern. The smaller example, of a rosy-ochre, is much smoother posteriorly and in the middle, but has the same character of ornamentation in a lesser degree. The presence of *Lepraliæ* on the larger specimen would seem to denote its mature condition, I may add that *Gari* Schum., 1817, has precedence one year over *Psammobia* Lm., 1818.

(ἐράσμιος, lovely.)

TELLINA (ARCOPAGIA) HABROTIMA, *sp. nov.*

(Pl. 1, f. 8.)

T. testa delicata, sordidé alba, umbonibus parvis, acutis, sed conspicuis, candidis, anticé ovata, posticé rotundata, margine dorsali lenté utrimque declivi, ventrali rotundato, arctissimé radiatim costulatis, et spiraliter similiter concentricé decussatis, costulis spinoso-lamellatis, interstitiis quadratis.

Alt. 13, lat. 15, diam. 4·50 mm.

Hab. Angrias Bank, Arabian Sea (Captain Tindall).

An exceedingly delicate, ornate shell, the sculpture being of a highly-chased radiate and concentric costulation, the interstices being quadrate. The radiate ribs are spiny, lamellate, in number about forty-six. In form, and general decussation this *Tellina* resembles most closely *T. carnicolor* Hanley, from the Philippines, the number of radiate ribs is, however, nearly doubled in that very finely sculptured species, the ribs being much thinner and finer. There is likewise strong superficial similitude to *T. costata* Sowb., but the umbones in that species are more elevated, the shell narrower by far, and the ribs only about thirty-two.

(ἁβρότιμος, delicately refined.)

TELLINA (MÆRA) ACTINOTA, *sp. nov.*

(Pl. 2, f. 1.)

T. testa parva, delicatula, oblonga, antice prolongata, postice curta, margine ventrali convexo, dorsali utrimque declivi, superficie delicaté concentrico-striata, striis posticé paullum squamatis, pulcherrimé puniceo-radiata ab umbonibus ad marginem ventralem, intus nitida, radiis conspicuis.

Alt. 6·50, lat. 9, diam. 3·50 mm.

Hab. Muscat, Arabia; 10 fathoms, coral sand.

A very beautifully rayed, and delicate species. It is allied to *T. semen* Hanley, *T. lechriogramma* Melv., etc., but we have not seen any of these near relations to it, in any instance, rayed. The concentric striæ are very delicate, and more pronounced posteriorly.

(ἀκτίνωτος, radiate.)

TELLINA (ANGULUS) SERICATA, *sp. nov.*

(Pl. 2, f. 18.)

T. testa subtrapezoide, delicata, tenui, pallidissimé albostraminea, umbonibus acutis, latere postico ab umbonibus rapidé declivi ad medium breviter truncato, antice peroblongo, margine ventrali convexiusculo, ab umbonibus ad extremitates posticas marginis ventralis valvarum unangulata, superficie triangulari inter angulum et latera postica spinifera, irregulariter noduloso-corrugata, cætera superficie concentricé lineata, lineis obliquis, irregulariter diffusis, transeuntibus, in medio magis arctis, hic sinuosis, illic, præcipae anticé, prope ventralem marginem evanidis.

Alt. 10, lat. 14, diam. 4 mm.

Hab. Muscat, Arabia ; 10 fathoms.

An ornate species, with a beautiful silky superficies, posteriorly angled and truncate, spiniferous, the space between the angle, which extends from the umbones to the posterior extremity of the ventral margin, is irregularly nodulously wrinkled. The shell, anteriorly, is very oblong, the surface shagreened with concentric lines, crossed obliquely and irregularly with other lines, these last becoming almost obsolete at the posterior extremity of the ventral margin. Not very nearly allied to any *Tellina* we are acquainted with. *T. gargadia* L. and *T. inæqualis* Hanley, especially the latter, have some characteristics in common with it, but are hardly comparable.

(*sericatus*, silken.)

PERIPLOMA INDICUM, *sp. nov.*

(Pl. 2, f. 4.)

P. testa inæquilaterali, inæquivalvi, valva sinistra minore, valvis ventricosulis, tenuibus, sordidé álbis, superficialiter irregulariter concentricé striatis, striis rudibus, umbonibus contiguis, incurvis, margine dorsali utrimque declivi, posticé curto, subtruncato, antice ovato-rotundo, margine ventrali convexiusculo, ab umbonibus usque ad lateris postici extremitatem unicarinata, carina obtusa, cardine in valva utraque obliquo, cochleari, intus alba, nitida, vix iridescente.

Alt. 12, lat. 15, diam. 5 mm. *sp. maj.*

Hab. Jask ; 4 to 6 fathoms, sand and mud.

Resembling in form, though not in texture, *P. trapezoides* Lam., from California. It is of a dirty white hue, smoothish, the left valve smaller than the right, umbones contiguous, incurved, ligament obscure externally, the shell dorsally declining on both sides of the umbones, the posterior side curtly truncate, the anterior roundly ovate, merging with the convex ventral margin, while an obtuse keel runs from the umbones to the posterior extremity in both valves. The hinge is oblique, spoon-shaped, one in each valve, the shell within is white, shining, not iridescent.

Seven or eight examples.

ADDENDUM.

Description of a new Strombus from the Mekran Coast of Beluchistan.

(Dredged by F. W. Townsend, Esq.).

BY JAMES COSMO MELVILL, M.A., F.L.S.

Received and read March 22nd, 1898.

STROMBUS (CONOMUREX) BELUTSCHIENSIS, *sp. nov.*

S. testa crassa, brevicula, coniformi, lævi, alba, epidermide læté olivacea contecta, anfractibus novem, quorum apicalibus duobus, tribus his proximis, parvis, infrá suturas spiraliter tornatis, cæteris irregularibus, applanatis ultimo magno, perlævi, spiraliter irregulariter squarrosé castaneo-maculato, infrá suturas obtusangulari, apertura angusta, oblonga, intus pallidé carnea, labro sinuoso apud basim, suprá excavato, margine columellari incrassato, polito, nitido, recto.

Long. 45, lat. 23 mm. *sp. maj.*

Hab. Charbar, Mekran Coast of Beluchistan, dredged at 7 fathoms, in mud and sand (F. W. Townsend, 1898).

Strombus belutschiensis.

I have made a brief allusion to this new *Strombus* in my last paper on the subject of Indian Ocean Mollusca.

Such a discovery is of very exceptional interest, for (since *S. mirabilis* Sowb., 1870, has been proved only synonymous with *S. Listeri* Th. Gray, 1852) no addition to the genus has been recorded since 1857, when Mr. Lovell Reeve described the still unique *S. taurus*.* This is more than forty-one years ago, and monographers have more than once expressed a pretty decided opinion that the genus might be considered complete.

It belongs to a section of the genus—*Conomurex* Bayle—characterized by the outer lip being hardly dilated, spire short, facies cone-shaped, aperture narrow. The abundant *S. mauritianus* Lam. (*cylindricus* Swn.) and *S. luhuanus* Linn., are the only other recent Conomurices.

The two specimens of *S. belutschiensis* before me only differ in size, and I have taken the larger for the type. The shell is thick, short, coniform, heavy for its size, the whorls covered with a smooth olive epidermis. The eight upper whorls, inclusive of the two apical, are all small, the third, fourth, and fifth are spirally tornate, the next three, with the larger lowest whorl, are smooth, irregularly formed, and gradate at the sutures, the last whorl is also obtusely angled and shouldered a little way below the suture, and is squarely, but irregularly, spotted and dashed with bright brown markings. The aperture is narrow, straight, interior light flesh colour, outer lip twice sinuous towards the base, excavate at the upper part, columellar margin white, incrassate, polished, smooth, and straight.

From all the many forms of *S. mauritianus* Lam. I have seen, it differs in this polished thickening of the columella, and the very stunted coniform shape.

It is hoped that the types of all the species in this and the preceding paper may be deposited in the British Museum (Natural History), S. Kensington.

* *Proc. Zool. Soc.*, 1857, p. 207, Pl. 37, fig. 3.

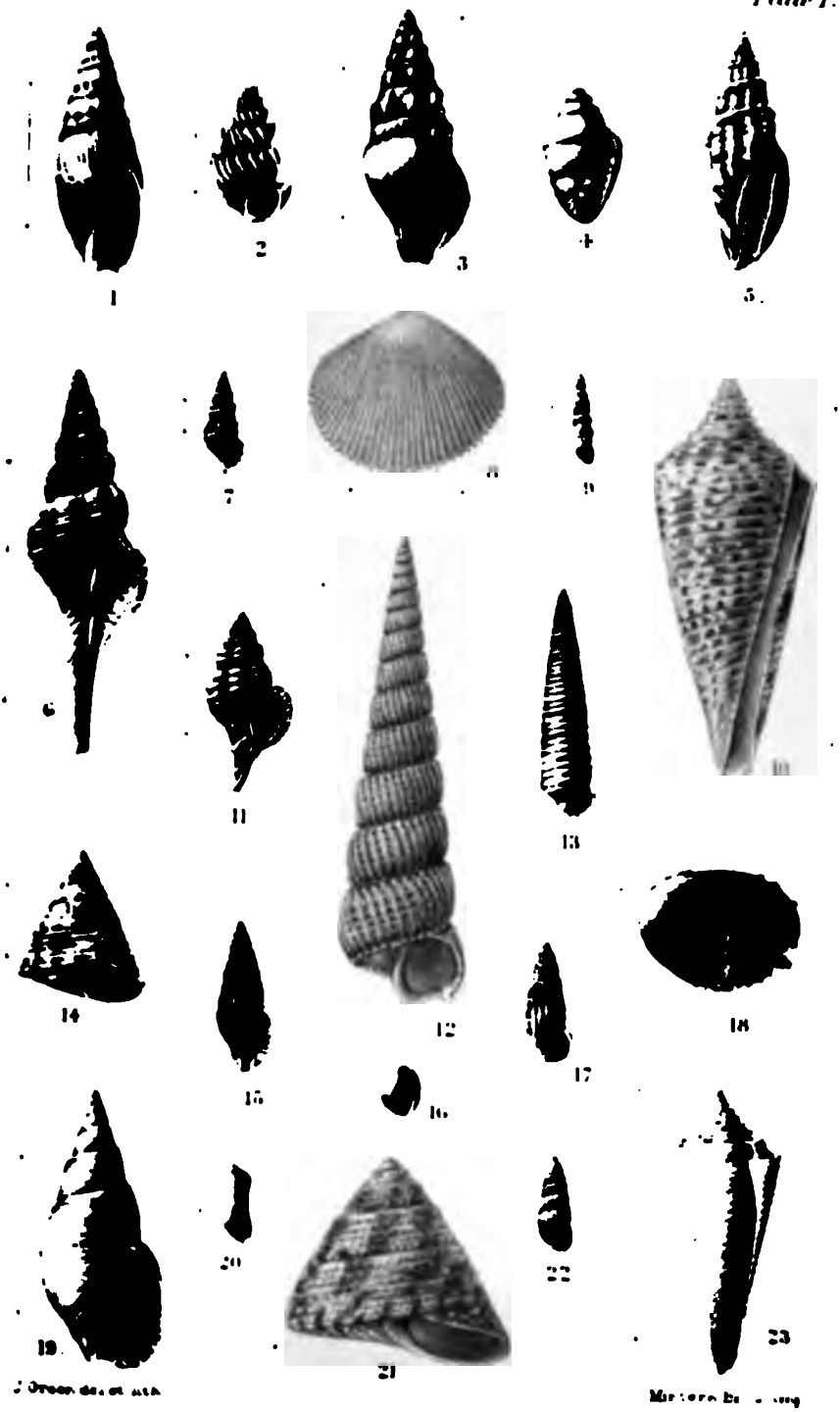
Explanation of Plates.

PLATE I.

Fig. 1. *Ancilla Tindalli.*
„ 2. *Scalaria malcolmensis.*
„ 3. *Pleurotoma* (*Drillia*) *angriasensis.*
„ 4. *Marginella* (*Glabella*) *quilonica.*
„ 5. *Cythara hypercalles.*
„ 6. *Fusus arabicus.*
„ 7. *Miralda opephora.*
„ 8. *Tellina* (*Arcopagia*) *habrotima.*
„ 9. *Turbonilla basilica.*
„ 10. *Conus* (*Leptoconus*) *dictator.*
„ 11. *Murex* (*Ocinebra*) *flexirostris.*
„ 12. *Scalaria fimbriolata* Melv.
„ 13. *Cerithiopsis* (*Seila*) *hinduorum.*
„ 14. *Calliostoma duricastellum.*
„ 15. *Clathurella camacina.*
„ 16. *Marginella* (*Persicula*) *oodes.*
„ 17. *Lachesis bicolor.*
„ 18. *Nerita* (*Heminerita*) *anodonta.*
„ 19. *Bullia* (*Pseudostrombus*) *indusica.*
„ 20. *Tornatina Townsendi.*
„ 21. *Trochus* (*Infundibulum*) *Fultoni.*
„ 22. *Turbonilla* (*Pyrgostelis*) *Manoræ.*
„ 23. *Conus* (*Leptoconus*) *sæcularis.*

PLATE 2.

Fig. 1. *Tellina* (*Mœra*) *actinota.*
„ 2. *Lima* (*Limatula*) *leptocarya.*
„ 3. *Gari erasmia.*
„ 4. *Periploma indicum.*
„ 5. *Eulimella kaisensis.*
„ 6. *Turbonilla* (*Pyrgostelis*) *templaris,*
„ 7. *Yoldia clara.*
„ 8. *Pleurotoma* (*Drillia*) *resplendens.*
„ 9. *Circe nana.*
„ 10. *Plicatula pernula.*
„ 11. *Diplodonta genethlia.*
„ 12. *Terebra Edgarii.*
„ 13. *Bullia ceroplasta.*
„ 14. *Ostrea Townsendi.*
„ 15. *Leucotina gratiosa.*
„ 16. *Basterotia arcula.*
„ 17. *Mytilicardia Ffinchi.*
„ 18. *Tellina* (*Angulus*) *sericata.*



MARINE MOLLUSCA

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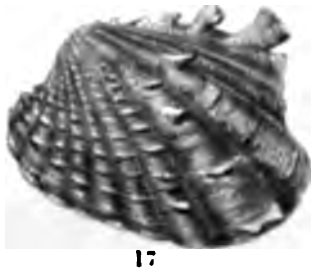

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Manchester Memoirs, Vol. xlii. (1898), *No.* 5.

V. On a Method of Determining the Thermal Conductivities of Salts, with some results of its application.

By Charles H. Lees, D.Sc.

Received and read December 14th, 1897.

In the course of a recent investigation on the thermal conductivities of mixtures of substances, and their dependence on the conductivities of their constituents, I required the conductivities of crystallised zinc sulphate and some other salts, and had to devise a means of determining them. The methods usually adopted in determining a thermal conductivity, require a disc or plate of the substance, and are therefore difficult to apply to salts in the form of powder or discontinuous crystals. A method of experimenting which has often been used for the determination of the physical properties of small bodies of irregular shape, may, however, be used with advantage. This consists of immersing the body in a liquid which possesses the particular physical property to be determined, to nearly the same extent as the body to be tested, and observing whether the property of the liquid is changed in magnitude by the presence of the body. If a change is perceived, another liquid is tried, till eventually one is found for which no change occurs, and which, therefore, possesses the property in question to the same extent as the immersed body.

In applying this method to the determination of the thermal conductivity of a salt, the salt in a rather fine state is mixed with water, or with a mixture of water and

alcohol the thermal conductivity of which is known, and the conductivity of the mixture of salt and liquid observed. If it is greater than that of the liquid, a better, and if less, a worse, conducting liquid is used, the operation being repeated till no apparent change in the conductivity of the liquid is produced by the addition of the salt. To prevent chemical action going on during the test, the liquid is previously saturated with the salt, and the thermal conductivity of the saturated liquid either determined experimentally or calculated from Jaeger's* results.

The range of conductivities over which the method can be strictly applied, is limited by the conductivities of the liquids available, but it has been used over a wider range in order to supply some approximate information in a field in which our previous knowledge was nil. In most cases only a rough approximation to equality of conductivity of liquid and salt has been made.

The apparatus, which was that used by me in determining the variation of conductivity with temperature, has been described elsewhere in detail,† and will only be described shortly here. It consisted of two discs of copper, 4 cm. in diameter and ·3 cm. thick, cemented to opposite surfaces of a glass plate of the same diameter and ·281 cm. thick. To the free surface of one copper disc, a flat spiral coil of insulated platinoid wire was attached, and the other free surface rested on a horizontal ring of ebonite ·326 cm. thick, 3·8 cm. internal and 7 cm. external diameter, supported on, and cemented to, a third copper disc 7 cm. diameter and ·3 cm. thick. This disc was placed on the top of a metal box, through which water circulated. The liquid, or mixture of salt and liquid to be experimented on, was placed within the ring of ebonite, and the smaller copper discs pressed onto it till

* *See* Landolt und Börnstein, *Tabellen.*

† *Phil. Trans.*, 1897.

they rested on the ebonite. An electric current was then sent through the spiral coil, the temperature of the upper disc was raised, and heat flowed through the glass plate and liquid to the lower disc and water bath. The temperatures of the various discs, when "steady," were determined by means of thermojunctions soldered into holes in the discs, a galvanometer, and a wire of known resistance through which a known current was passing.

The following results have been obtained for a mean temperature of 15°C.:—

Substances.	*Thermal Conductivity (c.g.s. units)*
Water	·0014
Sulphates.	
$CuSO_4 + 5H_2O$	between ·0017 and ·0018
$ZnSO_4 + 7H_2O$	„ 14 „ 15
$FeSO_4 + 7H_2O$	„ 13 „ 14
$NiSO_4 + 7H_2O$	„ 11 „ 12
$MgSO_4 + 7H_2O$	„ 11 „ 12
Sulphides.	
FeS	about ·017
CuS	about ·014
PbS	between ·0015 and ·0016
Oxides.	
Al_2O_3 (Emery)	about ·025
ZnO	„ ·009
CuO	„ ·008
PbO	„ ·005
Pb_3O_4	„ ·005
Fe_2O_3	„ ·003
MgO	„ ·003
Chlorides.	
KCl	·014
NaCl	·013
$PbCl_2$	·0013
$CuCl_2$	·0013

For comparison, I give the mean values quoted by Graetz* for metals, and the values found by me for sulphur.†

Cu	·9
Al	·5
Mg	·4
M	·3
Fe	·16
Ni	·1
Pb	·08
S	·0004 to ·0006

The values for salts whose conductivities lie between those of water and alcohol, have been determined by the method described, those above that of water by interpolation on the assumption that NaCl in particles has the same conductivity as in bulk (rock salt). The latter, as absolute values, may be wrong to a considerable extent, but the order of the various substances in the above tables is not likely to be seriously affected by subsequent more accurate work.

From the above results the following conclusions can be drawn :—

(1) A good conducting metal does not always confer good conductivity on its salts.

(2) The presence of water of crystallisation in a salt seems to bring the conductivity near to that of water.

(3) The chlorides of the alkali metals are good thermal conductors.

(4) Sulphides and oxides of the metals are comparatively good conductors.

(5) No direct connection appears to exist between the thermal conductivity of a salt and the conductivities of its elements.

* Winkelmann, *Handbuch der Physik*, Bd. III.

† *Phil. Trans.*, 1892 and 1897.

Manchester Memoirs, Vol xlii. (1898), *No.* 6.

VI. On the Mechanical Equivalent of Heat.

By OSBORNE REYNOLDS, F.R.S.,

Professor of Engineering, Owens College,

AND

W. H. MOORBY, M.Sc.,

Late Fellow of Victoria University, and 1851 Exhibition Scholar.

[*A condensed account of the matter of the Bakerian Lecture*;* *published under the condition of the Joule Fund, "to the honour of Joule's name."*]

PART I.

On the Method, Appliances and Limits of Error in the direct determination of the Work expended in raising the temperature of Ice-Cold Water to that of Water Boiling under a pressure of 29·899 inches of Ice-Cold Mercury in Manchester.

By Professor OSBORNE REYNOLDS.

The prestige conferred on this Society by Joule's intimate and lifelong association with it, renders it the high privilege as well as the duty of all its members to foster the fame of that great discoverer, and to guard with the most jealous eye the memory of his work against whatever may detract from the estimation in which it is held.

With these views, the author cannot bring before this Society the results of an independent determination of the *Mechanical Equivalent of Heat* without a word of explana-

* *Phil. Trans.*, A., vol. 190, 1897, pp. 301-422.

[The Council of the Royal Society have kindly permitted the use of the diagrams, pp. 30-34, prepared to illustrate the original paper.]

tion of the circumstances and motive which led to the undertaking.

In the experimental comparison of physical quantities in different modes, such as heat and work, the measured results depend not only on the aptitude and foresight of the experimenter and on the particular units employed, but involve fundamentally the standards to which the units are referred. Thus, in a repetition of the experiments, however accurate, the results should not agree unless the standards employed are the same.

Now Joule's standard of temperature-measurement was the scale of his thermometer (*b*), which is now in the custody of the Society, and which has not been used in any other determination.

Other determinations have been made by various observers with various thermometers, and the results are various which, though none of them differ by more than 1 % from Joule's values—772·69 (1849), 772·55 (1878)—, are on the average higher than Joule's. And, as the result of two researches (Rowland and Griffiths), there had, before 1890, been serious proposals, published in the *Transactions of the Royal Society*, to adopt the number 778 instead of J or 772.

As a member of this Society, the author felt strongly averse to this proposal, and not only so, but, from a study of the published papers, convinced himself that, notwithstanding the improved laboratory conveniences, the methods and means by which these later results were obtained, were, quite apart from Joule's wonderful aptitude, in no way comparable with those of Joule ; still he did not then feel competent, even had he been able to do so, to attempt a verification of Joule's results ; for it seemed to him a mere impertinence to publish results either as verifying or correcting those already obtained except with the fullest assurance that the requisite means, aptitude,

skill, experience and devotion are at least equal to those which have been already employed.

It was only on the occurrence, five years later, of circumstances which seemed to afford an opportunity, such as might not again occur, of obtaining the measure, in mechanical units, of the total heat necessary to raise water from 32° to 212°, the physically fixed points of temperature, and of thus placing the heat, in mechanical units, on the same footing as the unit of heat defined by temperature, without the intervention of the scales of thermometers, that the research was contemplated, and then after considerable hesitation.

The recognition of the responsibility even in attempting such a determination, and the harm to science that might follow from further confusion owing to errors in what, in spite of opportunities, must be the extremely difficult task of making such a complex determination within less than the thousandth part, together with the author's inability to devote the time necessary, prevented any attempt until July, 1894. At that date Mr. W. H. Moorby offered to devote himself to the research, and so to relieve the author from all responsibility except that which attached to the method and appliances, so that having, from experience, formed the highest opinion of Mr. Moorby's qualification, there appeared no excuse for further delay, particularly as, after seeing the appliances, both Lord Kelvin and Dr. Schuster expressed strongly their opinions as to the value of the research.

The opportunity for the research consisted in the inclusion in the original equipment of the Whitworth Engineering Laboratory, in 1888, of the following appliances:

1 A set of special vertical triple-expansion steam engines, with separate boiler, closed stoke-hold and forced

blast, capable of running steadily at any speeds up to 400 revolutions a minute, and working up to 100 H.P., especially arranged to give access to the shaft three feet above the floor.

(2) A special hydraulic brake dynamometer, on an extension of the engine shaft. This brake, which is shown in *Figs.* 1 and 2, is capable of absorbing any power up to a maximum of 30 H.P. at 100 revolutions a minute, increasing as the cube of the speed, so that it is capable of absorbing the whole power of the engines at any speed above one hundred revolutions a minute.

The whole of the work is absorbed by the agitation of the water contained in the brake, while the heat so generated is discharged steadily by a stream of water through the brake, with no other functions than of affording means of regulating the temperature of the brake, and the quantity of water in it. The moment of resistance of the brake is a definite function of the quantity of water it contains. And as, except for this moment, the unloaded brake is balanced on the shaft, the load being suspended from a lever on the brake at four feet from the axis of the shaft, if the moment of resistance of the brake exceeds the moment of the load, the lever rises and *vice versâ*. By making the lever actuate valves which regulate the inlet and outlet streams, the quantity of water in the brake is continually regulated to that which is just sufficient to suspend the load with the lever horizontal, and a constant moment of resistance is thus maintained whatever may be the speed of the engines.

(3) Manchester Town's water, of a purity expressed by not more than 3 grains of salts to the gallon, brought into the laboratory in a 4in. main at town's pressure (25 to 50lbs. per square inch), and distributed either direct from the main, or at constant pressure from a service tank 10ft. above the floor of the laboratory.

(4) Two tanks, each capable of holding 60 tons of water, one in the tower 116ft. above the floor, the other 15ft. below, connected by 4in. rising and falling mains, each 500ft. long, passing through the laboratory in a chase beneath the floor. The rising main includes a special quadruple centrifugal pump, 2ft. above the floor, capable of raising one ton a minute from the lower to the upper tank, also a set of mercury balances in the laboratory, showing the pressures in the rising and falling mains and the levels in the two tanks.

(5) A special quadruple vortex turbine supplied from the falling main, and discharging into the lower tank, capable of 1 H.P., and available for steady speed at all parts of the laboratory.

(6) A supply of power to the laboratory by an engine and boiler, quite distinct from the experimental engine, and distributed by convenient shafting always running.

The existence of these appliances, with all their specialities, was largely owing to the interest in educational work taken by Mr. William Mather, who, together with the other members of the firm of Mather & Platt, afforded facilities to the author and inspired that enthusiasm in the execution of the novel and special work which alone rendered it possible.

Of these appliances the brake is the centre of interest, as it was in this that the work has been measured as well as converted into heat.

A description of this brake has already been published, together with that of the engines,* and it is here only described so far as is necessary for reference.

The brake consists primarily (1) of a brake wheel 18in. in diameter, fixed on the 4in. brake shaft by set-pins, so that it revolves with the shaft (*Figs.* 2 and 3), (2) of

* Triple Expansion Engines, by Professor Osborne Reynolds, *Proc. Inst. C.E.*, 1889-90. Part I., p. 18.

a brake case (or brake) which encloses the wheel, the shaft passing through bushed openings in the case, which it fits closely so as to prevent undue leakage, while leaving the shaft and brake wheel free to turn in the case, except for the slight friction of the shaft. (*Figs.* 1, 2, and 3.)

The outline of the axial section of the brake wheel (*Fig.* 3) is that of a right cylinder 4in. thick. The cylinder is hollow—in fact, made of two discs bolted together, which form an internal boss for attachment to the shaft, and also meet together at the periphery—forming a closed annular box, except for apertures to be further described. In each of the outer disc faces of the wheel are 24 pockets (*Fig.* 2) carefully formed, 4½in. radially, 1½in. axially, but so inclined that the narrow partitions or vanes (¼in. thick) are nearly semicircular discs inclined at 45° to the axis; those in one of the disc faces being perpendicular to the opposite vanes in the opposite face.

The internal disc faces of the brake case are the exact counterparts of the disc faces in the wheel (except that there are 25 pockets), so that the partitions, or guides, in the case, are in the same planes as the vanes meeting them in the wheel. The clearance between the two faces is $\frac{1}{64}$in.

The pairs of opposite pockets when they come together form nearly closed chambers, having sections, parallel to the vanes, nearly circular. In such spaces vortices inclined at 45° to the axis of the shaft may exist, in which case the centrifugal pressure on the outside of such vortices will urge the case and wheel in opposite directions inclined at 45° to the direction of motion of the wheel, which will give a tangential component stress over the section of the vortices, between the wheel and case, of $1/\sqrt{2}$ of the sum of the pressures in the vortices.

The existence and maintenance of these vortices is ensured by the radial centrifugal force of the water in the pockets of the wheel owing to its motion.

This is the late Mr. William Froude's arrangement, but an essential feature of this brake is the provision which secures atmospheric pressure at the centres of the vortices, and admits of the pockets being only partially filled.

The effect of the vortex motion is to ensure a greater pressure towards the outside of the vortices than at their centres, but, as the tangential stress is the mean pressure over the section of the vortices, if the pressure at the centres of the vortices is allowed to fall, this stress will be diminished more or less. Thus, to secure regular stress, it is necessary to secure regular pressure at the centres of the vortices, and to obtain the maximum stress it is necessary that the central pressure shall be that of the atmosphere.

In order to secure these conditions, and at the same time to allow of the pockets being only partially filled—that is, to allow of hollow vortices with air cores at atmospheric pressure—it is necessary that there should be free access of air to the centres of the vortices. Such access cannot be obtained through the water which completely surrounds these centres between the vanes and guides. It is therefore obtained by passages (⅛in. in diameter) within the metal of the guides, which lead into a common passage opening to the air on the top of the case. (*Figs.* 2 and 3.)

In order to supply the brake with water, there are similar passages in the vanes of the wheel leading from the box cavity within, which again receives water through ports (*Fig* 3), leading from an annular recess in one of the disc faces of the case, into which water is led by means of a flexible india-rubber pipe from the supply-regulating valve. The water on which work has been done leaves the vortex pockets through the clearance between the disc surfaces of the wheel and the case, and enters the annular

chamber between the outer periphery of the wheel and the cylindrical portion of the case, which is always full of water when the wheel is running, whence its escape is controlled by a valve, in the bottom of the case, from which it passes to waste.

By means of linkage, connected with a fixed support and the brake-case, automatic adjustment of the inlet and outlet passages is secured according to the position of the lever, without affecting the moment on the brake-case, and this linkage also affords a means of adjusting the position of the lever when working. (*Figs.* 2 and 4.)

To admit of adjustment for wear the shaft is coned over those portions which pass through the bushes, the bushes being similarly coned to receive the shaft and screwed into short sleeves on the casing, so that by unscrewing them the wear can be followed up, and undue leakage prevented. (*Figs.* 2 and 3.)

The brake levers, for carrying the load and balance weights, are such as allow the load to be suspended from a groove in the lever, parallel to the shaft, at 4ft. from the shaft by a carrier with a knife-edge, the carrier and the weights being each adjusted to 25lb. (*Figs.* 3 and 4.)

In addition to the load, a weight is suspended from a knife-edge on the lever nearer the shaft, this load being the piston of a dash-pot in which it hangs freely except for the viscous resistance of the oil (*Fig.* 4). This weight is adjusted to exert a moment of 100 foot-lbs., and a travelling weight of 48lb. is carried on the lever, and worked with a screw of ½in. pitch, so that one turn changes the moment by two foot-lbs., while a scale on the lever shows the position. A shorter lever on the opposite side carries a weight 74·6lb. adjusted to balance the lever and riding weight when the load and dash-pot are removed.

The principle of these hydraulic dynamometers is that

when moment of momentum is introduced into a fixed space without altering the moment of momentum within that space, the rate at which moment of momentum leaves the space must equal that at which it enters. The brake wheel imparts moment of momentum to the water within the case, and the friction of the shaft imparts moment of momentum to the case. If, therefore, the moment of momentum of the water in the case is steady, the water must impart moment of momentum to the case as fast as it receives it from the wheel, and the time-mean of the moment of the load must be equal to the time-mean of the moment of effort of the shaft, and this is not affected by water entering or leaving the case as long as it enters and leaves it radially. The condition of steadiness is, however, essential in order that the moment of effort may at each instant be equal to the moment of resistance, since any change in the moment of momentum of the water is the result of the difference of the moments of effort and of resistance.

Fluctuations in the speed of running may thus cause two classes of error, even when the load has been constant all the time. (1) A terminal error resulting from a difference in the moments of momentum of the water at starting and ending the measurements. The relative magnitude of this error is the difference of the terminal moments divided by the product of the mean moment of the load and the interval of time in seconds; so that as the length of the time increases this will become indefinitely smaller. (2) The difference between the time-mean of the moment as measured by the load, and the angular mean of the actual moment which measures the work. This error can only occur where both the moment of effort on the wheel and the velocity fluctuate. With the automatic adjustment of the resistance, such fluctuations are limited to those of so short a period that they do not give the water

time to adjust, that is, they are limited to the fluctuations which occur in a single revolution of the engines. Fluctuations of this kind occur in all reciprocating engines from causes which are well-known and hence admit of estimation, and by such estimation the limits of errors from this cause have been found to be such that at 300 revolutions a minute the relative error would be less than one forty-thousandth part.

Besides these fundamental errors, the effect of the friction of the automatic gear (*Fig.* 4) had to be considered. In designing the brakes, it was hoped that the slight tremour to which they would be subject during their motion, would so far relax this friction that the gearing would adjust without pressure on the support, and this proved to be the case. The question of the dash-pot was also a matter of consideration; but so long as the viscosity of the oil is constant, and the passage for the oil to flow past the piston of constant dimensions, the time-mean of the resistance is simply proportional to the distance traversed divided by the time, so that, as the piston does not move through 0·1 ft. in an hour, this also became insensible.

The only other source of error in taking the product of the angle turned through and the moment of the load as measuring the work done, is possible end-play of the wheel in the case. This is very slight; it cannot exceed $\frac{1}{64}$ of an inch, while a side pressure of less than 50lbs. will always stop it; so that this again became negligible.

The exact determination of the moment of the load which involves the exact balance of the brake, and the measurement of the length of the lever and the weight of the load was, of course, necessary for the exact measurement of the work.

The development of the thermal measurements.

The appliances were originally designed in 1887, for the purpose of the study of the action of steam in the engines and certain problems in hydraulics and dynamometry, without any intention of their being used for the purpose of determining the heat-equivalent of the work absorbed. It was obvious that, as the measured work was all spent in heating water, it was only necessary to measure the change in temperature and quantity of the water used to obtain an approximate estimate of the heat-equivalent, but the recognitition of the extreme difficulty of obtaining any first-hand assurance as to the accuracy of scales of thermometers, and the fear of creating erroneous impressions as to the value of the equivalent, prevented the making of any provision for the introduction of thermometers in the first instance.

But after the engines and brake had been in use for two years, and had been found to possess attributes in steadiness of running and delicacy of adjustment and balance beyond expectation, and particularly to be able to work with an almost absolutely steady current of water through the brake, doing steady work whatever the speed and load, the author recognised that, by working two trials with the same thermometers, on the same parts of the scales, and with the same loads and the same temperatures of water, but at different speeds, since the relative balance of the brakes would be the same, the difference of the results of the two trials, made under the same surrounding temperatures, would afford the means of determining the loss of heat by radiation, and, this being known, the differences of two trials, both made at the same water temperatures as the previous, and both at the same speed but with different loads, would afford data for determining the error of balance, without introducing the value of the equivalent, or the scales of the thermometers except to identify equal

temperatures. He then yielded to the general wish in the laboratory, and added such provision to the brake as would admit of the measurement of the heat carried away by the effluent water, but only for verifying the accuracy of the balance of the brake as determined by mechanical tests, which, owing to the friction of the shaft, was difficult and only practicable to about one foot-pound.

The supply of water to the brake came from the service tank, 10ft. above the floor and 7ft. above the shaft; the tank being supplied through a ball-cock direct from the town's main; the pipe from the tank passing under the floor to a point conveniently close to the brake, thence by a branch rising vertically through the floor, in which there is a hand-cock, and above this, at a height of 4ft. above the floor, the automatic inlet valve. From this the pipe turns horizontal until over the inlet into the brake, where it ends in a mouthpiece facing the inlet, with which it is connected by a flexible india-rubber pipe (*Figs.* 1 and 4). The first provision made for measuring the temperature of the entering water was an aperture in the bend over the inlet valve with a vertical ⅜in. brass tube, soldered in, about 4in. long; this admitted an india-rubber cork, through the centre of which a thermometer was passed down into the pipe. This was subsequently replaced by a glass thermometer chamber.

To measure the temperature of the leaving water, it was necessary, by means of a pipe fixed to the mouth of the outlet valve, to lead the effluent stream above the balancing lever of the brake and to one side of it. This pipe was arranged so as to admit of the introduction of a thermometer much in the same way as the other. In the first instance, the extension-pipe and the thermometer were all rigidly attached to the brake and moved with it, which entailed a re-balance of the brake. Subsequently another arrangement was made. The thermometers used in the

first instance were divided to fifths of a degree Fahrenheit; they were both immersed in the flowing water to within a few degrees of the top of the mercury. They were compared at equal temperatures, but otherwise subjected to no tests for accuracy of scale.

During the experiments, the link connecting the inlet valve to the automatic gear was removed, the valve being set open and the supply regulated by the hand-cock below. The pressure in the brake being that of the atmosphere, and the head of water on the inlet constant at 7ft., when the hand-cock was set, the flow was steady. The quantity of water in the brake then depended on the automatic adjustment of the outlet valve, which, with the exception of a little trouble at starting and stopping the engines, soon overcome, kept the brake lever steady.

To admit of catching the water after leaving the outflow thermometer, the extension-pipe turned downwards over the side of the lever into a small basin, with its lip above the mouth of the pipe and from the basin the water flowed into a short trough, from which it was caught in buckets and carefully weighed. This was a primitive arrangement, and required several assistants, but was found capable of considerable accuracy up to about 40lb. a minute.

The engines were kept running at a constant speed by keeping constant pressure in the boiler, the speed being indicated on the speed gauge as well as recorded on the counter.

The water coming from the town's main was at nearly constant temperature, between 40° and 50° Fahrenheit, according to the time of the year, and varying less than a degree throughout several trials.

The rise of temperature was adjusted by the quantity of water admitted, according to the work, so that the final temperatures, as well as the initial, were as nearly as possible the same in the different trials.

The rise was generally such as admitted of the temperature of the brake being the same as that of the laboratory, which could always be adjusted to about 70° Fahr. The rise was thus from 25° to 30°, which, with 40lb. of water a minute, required from 25 to 30 H.P.

Before commencing the measurements everything was adjusted, and the engines running at steady speeds with constant load until the thermometer showed the temperature to be steady. Then, at a signal, the counter was put in gear and the water caught. The water thermometers, and one showing the temperature of the laboratory, being read at minute intervals over 15 or 30 minutes, when, on a signal, the counter was removed and also the last bucket.

The results of these tests were very consistent within about 0·3 per cent, which was within the limits of accuracy then aimed at. Trials with equal loads and different speeds showed that the loss of heat by radiation was very small, while those at the same speeds with different loads showed that the balance was within the limits determined by mechanical tests.

In these trials the only correction was that for the lubricating water which escaped from the brake bushes. This was caught at each bush, and the temperature taken so that the heat might be added, but this was seldom more than 0·3 per cent.

It is also to be noticed that in these trials the heat lost or gained by conduction to or from the shaft was included in the radiation. The brake being on an overhanging shaft, which extends no further than the outer bush of the brake case, the only conduction is on the side at which the shaft is continuous, where the brake shaft is only some 4 inches from the brass of the shaft bearing. The temperature of the brake on this side, which is opposite to that at which the cold water enters, was kept by the lubricating water at the temperature of the effluent

water, which was the temperature of the laboratory, so that there would be no cause of conduction unless the temperature of the shaft bearing was raised by friction. When the lubrication was good this was small, although on one or two occasions it made itself felt.

The idea of raising the temperature from 32° *to* 212°.

These tests became an annual, and very instructive exercise. But as the value of the equivalent was then a subject of much discussion, the desire to obtain measures of it from these trials by those engaged in them, resulted in Mr. T. E. Stanton, M.Sc., then senior demonstrator in the laboratory, effecting, for his own satisfaction, a comparison of the scales of the thermometers used in these experiments with a thermometer used in the physical laboratory, which had been corrected by the air thermometer, and introducing the corrections into the results of these trials, which so gave values very close to what might be expected.

The author could not, however, see that determinations based on such corrections could have any intrinsic value, but as the matter was exciting great interest in the laboratory, he carefully considered the conditions which would be necessary to render the great facilities which the brake was then seen to afford, available for an independent determination.

The institution of an air thermometer was considered and rejected, but it occurred to the author that it might be possible to avoid the introduction of the scales of thermometers just as before, and yet obtain the result. If it could be arranged that the water should enter the brake at the temperature of melting ice, and leave it at the temperature of water boiling under the standard pressure, all that would be required of the thermometers would be the identification of these temperatures.

At first the difficulties looked formidable, but on trying by gradually restricting the supply of water to the brake when absorbing 60 H.P., and finding that it ran quite steadily with its automatic adjustment, till the temperature of the effluent water was within 3° or 4° of 212°, he further considered the matter, and formed preliminary designs for what seemed to be the most essential appliances to meet the altered circumstances. These involved :

(1) An artificial atmosphere; or a means of maintaining a steady pressure in the air passages of the brake of about four-thirds of an atmosphere.

(2) A circulating pump and a water cooler, by which the entering water, some 30 pounds a minute, could be forced through the cooler into the brake at a temperature of 32°, having been cooled by ice from the temperature of the town's main.

(3) A condenser by which the effluent water leaving the brake at 212° F., might be cooled down to atmospheric temperature before being discharged into the atmosphere and weighed.

(4) Such alteration in the manner of supporting the brake on the shaft, as would prevent excess of leakage from the bushes in consequence of the greater pressure of air in the brake; since not only would the leaks be increased, but, when the rise of temperature of the water was increased to 180°, the quantity for any power would be diminished to one-sixth of what it would be for 30°, so that any leakage would have six times the relative importance.

(5) Some means which would afford assurance of the elimination of the radiation and conduction, as with a rise of 140°Fahr. above that of the laboratory, these would probably amount to two or three per cent of the total heat.

(6) Scales for the greater facility and accuracy in weighing the water, with a switch actuated by the counter.

(7) A pressure-gauge (or barometer) by which the standard pressure for the boiling point might be readily determined at 3° or 4° above or below the boiling point, so as to admit of the ready and frequent correction of the thermometers used for identifying the temperature of the effluent water.

(8) Some means of determining the terminal differences of temperature and quantity of water in the brake, which would be relatively six times larger, with a rise of 180° than with 30°.

Having convinced himself by preliminary designs, not only of the practicability of the appliances, but also of the possibility of their inclusion in the already much occupied space adjacent to the brake, there still remained much to be done in the way of experimental investigation to obtain data for the determination of the requisite proportions of the appliances, and these preliminary investigations were not commenced till the summer of 1894, when Mr. Moorby undertook to carry on the research.

A convenient table weighing machine, with a tank to hold 1 ton of water, was obtained and placed on the other side of the passage, opposite the brake.

The outflow pipe was rearranged, a flexible tube being used to take the water from the brake to a fixed thermometer chamber. Glass thermometer chambers were constructed, so that both the thermometers were wholly immersed in the flowing water.

The effluent water was led from the thermometer chamber over the passage to the switch into the tank.

The switch was constructed so that it would divert the water from waste to the tank, or *vice versâ*, without any splash, and was subsequently connected with the counter, so that they both moved together (*Fig.* 6).

When these arrangements were completed, a series of experiments was commenced by Mr. Moorby, similar to

those already described, with a view to test the improved facilities, also to gain experience and facility in making and recording the observations. The engines being otherwise engaged two or three days in the week, every opportunity was valuable.

At the same time, experiments were in progress to ascertain the length of 1in. pipe necessary in order that water (20lbs. per minute) flowing through it might be cooled from 212° to 75°, when the pipe was jacketed by a stream of town's water at 50°. As the result of these a condenser 30ft. long was constructed.

After passing the condenser, the water was led vertically to a height of 5ft. above the chamber, thence past an air gap down again to the switch, so as to maintain a head of 5ft. in the chamber, to prevent bubbles forming in the water on account of the air it contained. This height was subsequently raised to 11ft.

In order to cool the water as nearly as practicable, without danger of ice being carried over, the cooler was designed so that the ice should be outside the pipe through which the water passed. This clearly required a considerable length of pipe, so that the resistance had to be taken into account. As the result of experiments, 200ft. of ⅜in. composition pipe was used in a coil, it being estimated that this would pass 20lbs. a minute, with a loss of pressure of 30lbs. on the square inch. This was placed in a tank of paraffined wood, and a paddle worked by the line shaft constantly circulated the water; the arrangement being designed to secure the coldest water passing along the coil.

To obtain the necessary head—30lbs. for the coil, 5 for the brake, and 25 for regulation—it was necessary to pump the water. It was also necessary that the flow should be steady. To obtain these ends, recourse was had to the 3in. quadruple turbine, driven by the water from

the tower, to drive a 1¼in. quintuple centrifugal pump in the circuit of the water between the service tank and the cooler, and in this way the requisite steady head was obtained.

These preliminary investigations and the construction of the appliances, so far described, were not completed till May, 1895. It then became possible to make experiments as to the working of the brake under pressure and at high temperatures, so as to obtain guidance as to the artificial atmosphere and means of controlling leakage at the bushes. These showed that the artificial atmosphere would be a simple matter. A strong vessel, made of tin plate, with a capacity of three gallons, was connected with the air passage on the top of the brake by a flexible tube. The vessel had two openings at the top besides that connected with the brake—one with a cock, to admit of air being forced in; the other with a fine screw stop, to allow of a definite escape of air. There was also a cock at the bottom, to drain water which might accidentally get in. A syringe was used for pumping in air at starting, while, during the trials, the small amount of air released from the water was more than sufficient to maintain the pressure.

On the other hand, these experiments showed that the increased leakage at the bushes was a very serious matter, and must be controlled.

The first step was to enclose the open end of the shaft by a cap screwed on to the bush, and the side on which the shaft was continuous by a stuffing-box, having small apertures controlled by cocks to regulate the outflow of water for lubrication. *Fig.* 5. The result was, however, far from satisfactory, as the lubricating water flowing out from the brake not only raised the shaft to a high temperature, but was itself of uncertain temperature. It was in July, 1895, that this experience was obtained, and

for a time the success of the research seemed doubtful. It necessitated the reconsideration of the whole scheme of working. This revealed to the author that it would be possible to reverse the course of the lubricating water, make it flow in at the bushes instead of out, and so not only maintain lubrication, but also cool the bushes and shaft. That this would be the result of forcing the water in at the bushes was tolerably obvious, but what was not obvious at first, was that there was already provision in the form of excess of pressure in the inflow pipe, between the cooler and the supply-regulating valve, to maintain this flow, by merely admitting a portion of the cooled water into the bushes by by-pipes with regulators, without passing it into the thermometer chamber. This water being taken from the inflow pipe before the rest passed into the thermometer chamber would be nearer 32°, but would be warmed by the radiation into the by-pipe, so that it would enter at a slightly uncertain temperature, but this would be a radiation effect, and would be eliminated with the other radiation effects. As soon as this became clear, the success of the research became assured. The work was executed by Mr. Foster, and, when complete, rendered it possible to keep the bushes at any required temperature.

In the preliminary trials this temperature was ascertained by touch, and regulated to that of the laboratory as nearly as possible, the cocks being set to a definite opening, and the excess of pressure maintained as nearly constant as possible. This plan was found to give consistent results. But it appeared that, in order to maintain the same temperature in the stuffing-box with the heavy as with the light trials, the pressures in the pipe being the same, it was necessary to open the branch cock wider in the heavy trials, on account of the greater vortex pressure in these trials. In commencing the final trials, the same setting of the cocks was maintained

in all the trials, a record being kept; so that, should any means of determining more definitely the relative slopes of temperature in the shaft be found, it could be used retrospectively.

Such a means of determining the relative slopes of temperature in the shaft between the stuffing-box and the near brass was obtained by sweating brass thermometer tubes, radiating outwards, on to the end of the stuffing-box and on to the brasses of the near bearing. It appeared to the author that these thermometers, although they did not indicate the temperature of anything in particular, would serve, the conditions being steady, by the difference of their readings to identify similar conditions as to slopes of temperature, and this turned out to be the case. A flood of light was thrown on to conditions which before had been hardly perceptible, and it became possible to observe the smallest differences in the slopes of temperature, thus ensuring the elimination of the conduction of the shaft (which had threatened to be a considerable, and the only considerable, source of error) to within 0·00002 of the heat in a single trial, and altogether negligible on the mean of 42 trials.

In order to relieve Mr. Hall, who had charge of the engines, from the necessity of maintaining the speed constant, a hand brake was arranged on one of the pulleys, by which the speed could be adjusted by one of the assistants, so as to keep the speed within something like 0·3 %. And the quantities of water in the brake for various loads and speeds having been ascertained by experiments, the terminal errors were obtained from the records of the initial and final speeds and temperatures.

The method of conducting the trials was designed to secure the most perfect elimination possible of the heat lost by radiation, and with this view, after the experience obtained in preliminary trials, it was arranged that all trials

should be in pairs at 300 revolutions a minute, the loads at first being—

Heavy trials 1,200 foot-lbs., about 70 H.P. on the brake
Light „ 600 foot-lbs., „ 35 H.P. „

The time of running one hour for each trial. The thermometers in the inlet and outlet chambers, also the temperature of the laboratory to be read every two minutes and maintained as constant as possible, and subsequently the thermometer on the stuffing-box and brasses to be read every eight minutes, and the speed gauge read every two minutes. The setting of the cocks and the pressures in the supply pipe and artificial atmosphere also recorded. All observations being recorded in ink in a book, and kept distinct from any reductions.

It was impossible to make trials simultaneously. And as the possible opportunities were subject to the regular work of the laboratory, in order to secure similar conditions as far as possible, it was at first arranged that each set should consist of at least four pairs of trials, taken in such order that the four heavy trials were not only made at hours of the day, but also on days in the week similar to those of the corresponding light trials.

Each such set of trials would afford means of determining the approximate radiation-constant, and show how far the radiation had been eliminated.

In order to obtain still further definite assurance of the elimination, it was arranged that, after consistent results had been obtained in several groups of four pairs of trials with the brake naked, the brake should be covered with non-conducting material in the best way practicable, so as to greatly reduce the radiation, at the same time leaving it definite, and then similar trials should be run. In this way, if the radiation could be reduced to one-fourth part of that with the naked brake, such error as there might be in the elimination with the

naked brake would be reduced to one-fourth part with the covered brake, provided no fresh errors, owing to the time taken to get the lagging at a steady temperature or owing to its absorption of moisture, intervened. Further, it was arranged that a similar plan should be adopted to obtain assurance of the elimination of errors resulting from each detailed circumstance that could effect the loss of heat, namely, that, where such circumstance could not be removed, its effect should be definitely varied and a fresh set of trials run, which plan seemed to afford the best possible means of determining the limits of error.

The leakage of water from the three working joints of the brake was a matter of first consideration and continual care. By continual attention to the stuffing-box and gland it was reduced to a very small amount. In so far as the leakage was equal in the light and heavy trials, the effect of such leakage would be eliminated; and, to ensure this, the water was caught, its temperature on leaving the brake measured, and the losses of heat allowed for, so that the possible limits of error from this cause, which were very small, were somewhat definitely ascertained.

The losses of water by evaporation from the surface in the tank, &c., were rendered as nearly as possible equal for the light and heavy trials by cooling all the water to a fixed temperature before exposure to the atmosphere, it being arranged that, after the experiments were over, the appliances should be so altered as to admit of the water in the weighing tank at the working temperatures being forced round the same circuit from the weighing tank back to the weighing tank, for one hour, at the rates of entrance in the light and heavy trials respectively, so that the actual losses in each of these trials should be ascertained.

By these means, definite estimates of the outside limits

of the error that might arise from each of the circumstances affecting the relative accuracy were provided, thus assuring the accuracy of the results obtained within these limits, in terms of the standard of measurements—length or temperature—to which they are referred. These limits are given in a table at the end of this Part.

The Standards of Measurements.

During the inception of the research, the appliances for standardising the results had been in course of preparation, in accordance with the system already mentioned as designed by the author.

Since the absolute quantity of mass does not enter into the results, it was only necessary to use a common standard in comparing the masses of water with the masses which formed the load on the brake. And for this purpose 12 of the 25lb. cast-iron weights used for the load on the brake were adjusted by balance, with a limit of accuracy of 0·01lb. of each other; then the scales, after being reset by Mr. Foster, were surveyed with the adjusted weight and the corrections fully determined. As the weights on the scales, as well as the adjusted weights exclusively used on the brake, were of the same material, it was not necessary to apply any correction for the weight of the atmosphere to these. And, since the water is balanced by cast-iron and the load is balanced by cast-iron, a correction for the weight of the atmosphere displaced by the iron would leave the relation between the load and the water the same; so that the only correction was for the weight of the atmosphere displaced by the water.

The standard capacity for heat being that of distilled water, this would have been employed in the experiments had it been practicable. But since, letting alone the extra appliances, the cooling the 100 tons of water from a temperature, say, of 72° to 32°, would have required more than

30 tons of ice, while with the water from the town's mains, at a mean temperature from February to June of 45° F., about 10 tons would suffice, town's water was used. And had it not been for the known purity of this water, the research would not have been attempted.

As affording definite assurance of the purity of the water, Professor Harold B. Dixon kindly furnished the result of the analysis he makes periodically for the Corporation from water drawn in the College. From this it appears that the effect of the salts dissolved is nearly negligible.

A much more important consideration was the effect of the air which is dissolved in all water, and particularly distilled water. It may be taken that the water used for the standard capacity of heat always contains this air, and it is only in such experiments as these in which the temperature of the water is raised to within one-third of an atmosphere of its boiling point that this air can produce any sensible effect, and it does not appear that this effect has hitherto been noticed. It is, of course, well known that when water is heated, before it boils, what are called air-bubbles rise to the surface, but on consideration it will appear that these are not altogether, nor chiefly, air-bubbles, but are filled with saturated steam corresponding to the temperature of the water, the function of the air being merely to support the excess of pressure whatever it may be. Hence the volume of these bubbles represents, in addition to the heat of the water evaporated, the latent heat of this water, and this, taking the weight of air as 0·003 per cent. of the water (the usual amount) and the excess of pressure $\frac{1}{3}$ atmosphere, the effect would be a relative error of 0·0003. It was to prevent this that the back pressure in the thermometer chamber was made as large as practicable. In this way, if the proportion of air leaving the water could be ascertained, allowance could be

made, and it was arranged that, after the trials, experiments should be made to determine this. For, although the limits of this error were within 0·03 per cent., they were much the largest in the research.

For the standard of length a series of Whitworth gauges and a brass scale, by Elliott, were used ; and from these a bar was prepared by Mr. Foster having parallel plane ends 30 inches apart, to be used for reference in all measurements, and preserved.

The standard of temperature being the interval between the temperature of ice melting under the pressure of the atmosphere and that of water boiling at the sea level in latitude 45°, under a pressure of 760 mm. of ice-cold mercury, reference to the barometer was necessary.

To verify thermometers at the higher temperatures with facility at any time, irrespective of the pressure of the atmosphere, and to secure ready verification of the absolute distance between the upper and lower surfaces of the mercury, the author designed a special barometer, in which the light over each of the surfaces of the mercury is cut off by the separate adjustment of two cylindrical brass curtains, the upper curtain screwing down over a slotted cylindrical prolongation of the lower curtain, which encases the tube and the lower vessel, screwing down on the latter. So that when the truly turned lips of the curtains are adjusted to read the barometer, say at 30″, the lower curtain can be screwed off the barometer and placed vertically over the 30″ bar standing on end on a surface plate, so that the lip of the curtain rests on the plate, when, as the relative positions of the curtains have not been altered, the light over the top of the bar should be just as it was seen over the mercury. The lower vessel is a cylindrical cast-iron bottle, with parallel plate-glass windows, and with the tube passing out through a stuffing-box, there being an aperture furnished with a nozzle for

connection with the vapour chamber in which the thermometers were placed.

The execution of this was undertaken by Mr. Foster, who has produced a very beautiful instrument, the mercury being re-evaporated in apparatus belonging to Dr. Schuster by his assistant, Mr. A. T. Stanton. The readings are easily taken, and verified to the ten-thousandth of an inch.

The correction on the thermometer for 32°F. was obtained in the usual way; but as there was no ready means, as with the higher temperature, of testing the scale of the thermometer for two or three degrees above 32°, this correction could only be made by comparison with the thermometer already compared with the air thermometer, and these comparisons Dr. Schuster kindly allowed to be made in the physical laboratory.

The corrections of the thermometers on account of the pressures in the thermometer chambers were also determined, while the limits of error, owing to the slight excess of the low temperature over 32°, were carefully considered and defined.

The question as to what should be done in the way of rejecting trials was also a subject of first consideration. It was certain that in such a research accidents must occur, and it was necessary to have some rule so as to prevent any sorting of the trials. It was therefore arranged to reject all trials in which there was definite evidence, either during the trial or in the results, of uncertainty in any one of the measurements to which no definite limits could be assigned, without regard to the apparent consistency of the results, and to retain all other trials.

After the conclusion of the trials, on opening the brakes, an estimate of the wear of the metal was made, from which estimates of the possible absorption of work in disintegrating the metal and of the production of heat in oxidizing the metal were obtained.

The several circumstances on which the accuracy of the results of the investigation depends, together with the relative limits of error as determined for each circumstance, and the formulæ of the relative corrections to be applied, are as follows:—

Circumstances and Formulæ of Correction.	Outside Limits of Relative Errors.
1. Terminal differences in the moments of momentum of the water in the brake	0·000000, − 0·000000
2. Cyclic fluctuations of speed of the engines	0·000025, − 0·000025
3. Work done on the water by end-play of the shaft...	0·000017, − 0·000000
4. Work done in the dash-pot ...	0·000000, − 0·000000
5. Effect of the automatic gear on the balance of the brake	0·000016, − 0·000016
6. Imperfect elimination of the error of balance of the brake	0·000000, − 0·000000
7. Imperfect elimination of the heat conducted by the shaft $-C\Sigma(T^{\circ}_{\beta} - T^{\circ}_{\beta})/\Sigma(H)$	0·000000, − 0·000000
8. Imperfect elimination of the heat radiated from the brake $-R\Sigma(T^{\circ}_{1} - T^{\circ}_{a})\ \Sigma(H)$	0·000010, − 0·000010
9. The engagement of the counter $+0{\cdot}000013$	0·000000, − 0·000000
10. The terminal difference of speed and temperature $-\Sigma\{(B + W_{i})T^{\circ}_{i} - (B + W_{f})T^{\circ}_{f}\}/\Sigma(H)$	0·000000, − 0·000000
11. Leakage of the stuffing-box; $-\Sigma W_{\beta}(T^{\circ}_{\beta} - T^{\circ}_{1})/\Sigma(H)$	0·000000, − 0·000025
12. Leakage at the automatic valve, 0·000000	0·000000, − 0·000000
13. Imperfect elimination of water lost by evaporation	0·000000, − 0·000000
14. Limits of accuracy in weighing the water	0·000025, − 0·000025
15. Weight of the atmosphere, − 0·001204	0·000000, − 0·000000
16. Correction for gravity to latitude of Greenwich	

Circumstances and Formulae of Correction.	Outside Limits of Relative Errors.
17. Correction for gravity to latitude 45°	
18. Salts dissolved by the water + 0·8s...	0·000000, − 0·000000
19. Air „ „ − 10·31a	0·000100, − 0·000100
20. Length of lever	0·000020, − 0·000020
21. Effect of pressure on the thermometers − $\Sigma\{W(e_1p_1 - e_2p_2)\}/\Sigma 180°W$)	0·000010, − 0·000010
22. Rise of the standard reading of the thermometers in the intervals of correction; + 0·5 (difference of rise /number of intervals) /180 ...	0·000000, − 0·000000
23. Difference between the initial temperature of the water and freezing; − 0·000028$\Sigma\{W(T_1° - 32°)\}/\Sigma(W)$	0·000000, − 0·000000
24. Work done by gravitation on the water :— − 0·000008$\Sigma\{W(P_1 - P_2)\}/\Sigma W$	0·000000, − 0·000000
25. Work absorbed in wear of metal ...	0·000010, − 0·000010
Total Limits of Error	+ 0·000233, − 0·000241

The quantities under Σ ( ) in the denominators of the corrections are to be taken positive for the large trials, negative for the small.

The significance of the symbols are as follows :—

C, the constant of conduction obtained from the trials.

R, the constant of radiation obtained by trials with the brake naked and lagged.

s and a, the relative weights of salts and air in the water.

p_1, p_2, the pressure in inches of mercury in the initial and final thermometer chambers.

e_1, e_2, the corrections, per inch of mercury pressure, on the initial and final thermometers.

W the weight of water in a trial; $W_{,3}$ the weight lost at the stuffing box; W_i weight of water in the brake at beginning, W_f at end of trial.

T° temperature Fahrenheit; $T_1°$ of water entering; $T_2°$ of effluent water; $T_{,3}°$ at stuffing-box; $T_\beta°$ at bearing; $T_a°$ of air; $T_i°$ at beginning, $T_f°$ at end of trial.

H, heat generated during a trial.

B, capacity of heat for the metal of the brake.

Fig. 1.

Fig. 2.

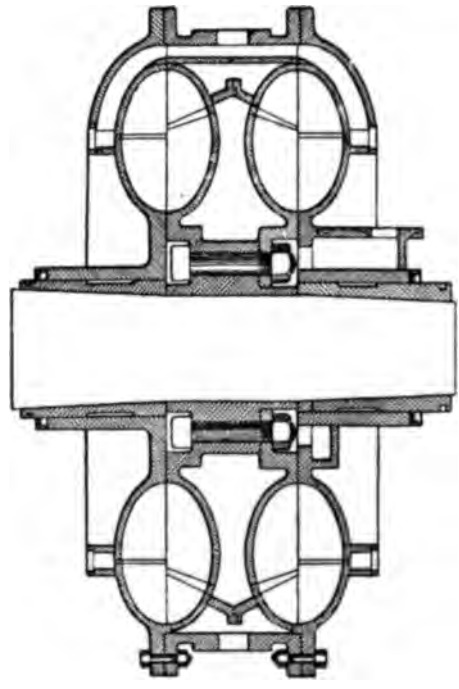

Fig. 3.

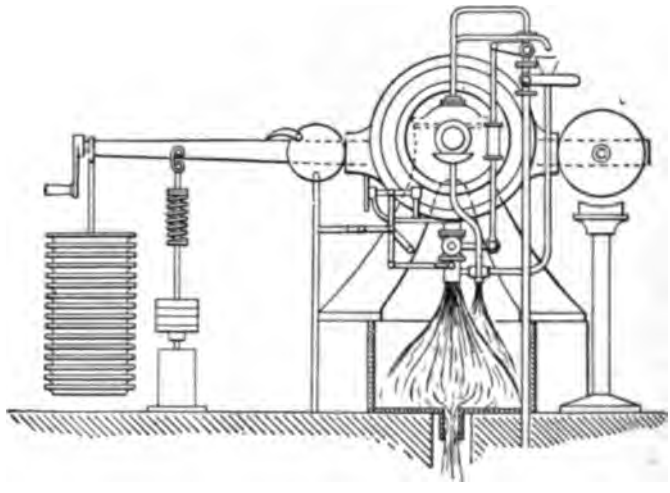

Fig. 4.

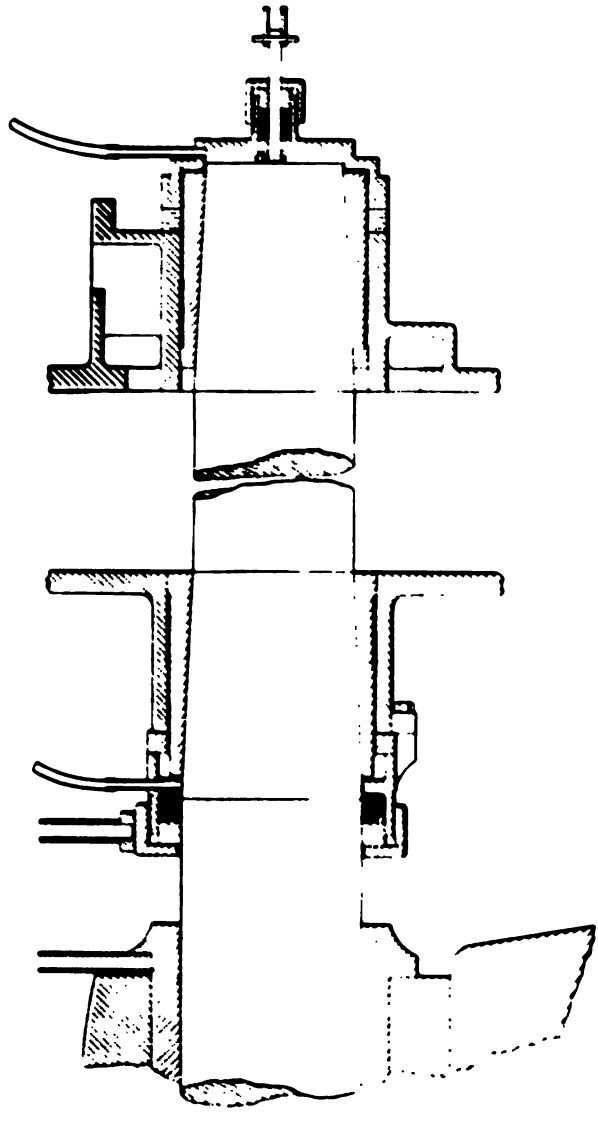

Fig 5.

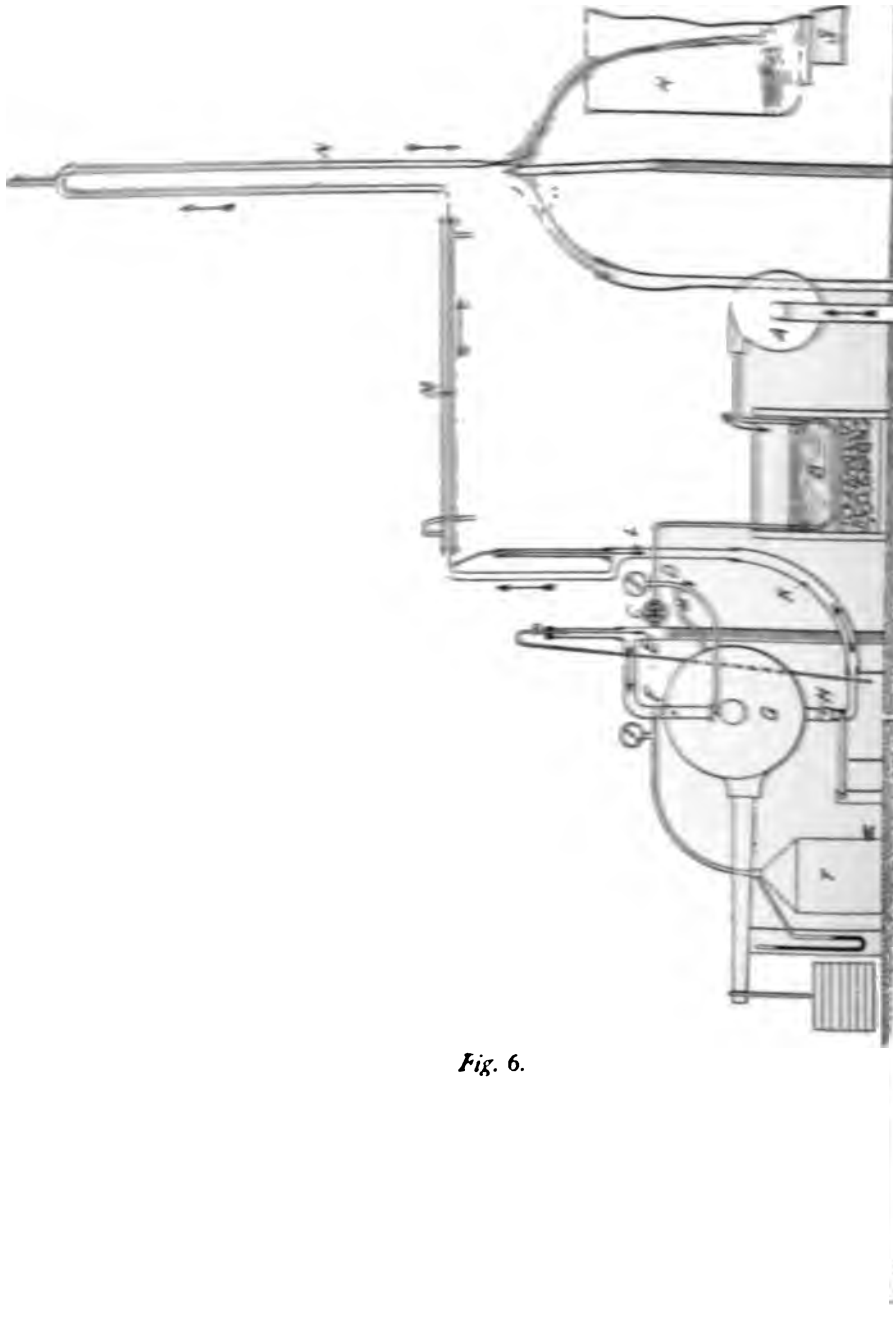

Fig. 6.

PART II.

On an Experimental Determination of the Mechanical Equivalent of the Mean Specific Heat of Water between 32° and 212° Fahrenheit, made in the Whitworth Engineering Laboratory, Owens College, on Professor Reynolds' Method.

By WILLIAM HENRY MOORBY, M.Sc.

1. *General plan of the Investigation.*

The Whitworth Engineering Laboratory, at the Owens College, is supplied, among other apparatus, with a 100 H.P. experimental engine, the whole of the work, if desired, being absorbed by one of Prof. Reynolds' hydraulic brakes. This brake maintains a steady turning moment on the shaft, which we may represent by M, for any trial. If N be the number of revolutions of the shaft in any time, then the total work done in the interval is $U = 2\pi MN$. The whole of this work is expended in raising the temperature of a stream of water flowing through the brake.

Let W = total weight of water in the interval, and dT = rise of temperature in the brake; then, neglecting all losses by radiation, &c., the heat generated = $H = W.dT$.

For some years past experimental determinations of the heat generated in the brake have been made to obtain evidence of the adjustment of the brake, to the limits of accuracy of the thermometers used, by equating the heat, multiplied by 772, to the work as measured. The chief difficulty met with in the endeavour to obtain reliable results by this method was in the calibration of the scales of the thermometers

In July, 1894, on my applying to him for some research work, Prof. Reynolds asked me to undertake the experimental part of a research (the method and appliances having been already devised) on the work expended in heating water from the freezing to the boiling point.

The method suggested was substantially that set forth below.

The stream of water was to be supplied to the brake at a temperature approaching as nearly as possible to 32°F., and was to be raised to a temperature of 212°F. before being discharged from it.

If these temperatures could be kept steady at the points indicated, two thermometers, the one in the supply pipe and the second in the discharge pipe, would be required; and their only function would be to supply a means of comparing, in the first case, the temperature of supply to that of melting ice, and, in the second case, the temperature of discharge to that of steam at the standard atmospheric pressure. Thus the calibration of their scales would be of no consequence.

In order to eliminate losses of heat by conduction along the shaft and by radiation from the brake, the trials were always to be made in pairs, the one carrying a moment of 1,200 ft.-lbs. on the brake, and the second a moment of 600 ft.-lbs. The duration of each trial was to be the same, viz., one hour. Consequently, since the same difference of temperature would exist in each case between the final temperature of the water and the surrounding air, the loss of heat by radiation would be sensibly the same in both, and the difference of work done in the two trials should be exactly equivalent to the difference of apparent heat generated; and by dividing the first of these quantities by the second, a value of the constant required would be obtained.

In addition to the very obvious advantages contained

in the plan suggested above, the power available for the purposes of the research enabled me to deal, in trials of one hour's duration, with quantities approaching the following values:—

Revolutions, 18,000.

Total work done, 135,000,000 ft.-lbs.

Total weight of water raised 180°F., 960lbs.

Total apparent heat generated, 170,000 B.T.U.

In quantities so large as these, some of the small errors inevitable to all physical experiments became quite or nearly negligible.

2. *Arrangement of the apparatus.*

Before the experiments could be begun it was necessary to specially arrange the line of piping supplying water to and discharging it from the brake. The course taken by the water in the apparatus as completed was as follows (*Fig. 6*):—

From the mains in the laboratory it was forced by a centrifugal circulating pump through a length of about 200ft. of ⅜in. diam. composition pipe, immersed in a well-stirred mixture of ice and water, with the object of cooling it to 32°F. From this pipe the water flowed into a glass tube carrying the thermometer which indicated the temperature of supply to the brake, the whole stem of the thermometer being immersed in the water and the readings being taken through the glass walls of the chamber. From this chamber the water was delivered through a flexible rubber pipe to the brake. Here its temperature was raised to 212°F. before being forced through a second rubber pipe into the fixed discharge pipe, which carried a second thermometer jacketted like the former one with the water whose temperature was required. The water was then cooled by passing through an iron condenser of the ordinary chemical pattern, and

delivered through a two-way tipping switch, either waste or into a tank which stood on the platform of a weighing machine. When the engine was running steadily, the discharge temperature could be regulated to the required point by means of a valve inserted in the supply pipe between the ice-cooler and first thermometer. If this valve was opened, more water was admitted to the brake, and consequently the temperature of discharge fell and *vice versâ*. By this means the temperature of discharge in most of the trials rarely varied by as much as 2° from the desired point, viz., 212°, and the mean temperature of discharge, as obtained from 30 observations in each trial, never varied by as much as 1° from 212°.

The temperature of supply varied between 32·7° and 34·3° according as the temperature of the water in the town's mains was lower or higher. In any one trial the supply temperature was exceedingly steady, often not varying through an interval of 0·1° through an hour's run.

3. *The various losses of heat.*

As it was likely that in a pair of trials the losses of heat would not be exactly the same, and that, therefore, some error would appear in the differences of work and heat used in the determination of the equivalent, an estimate was made of the losses of heat occurring by different means in any trial.

These losses were as follows:—

(1) *Loss by radiation:*

The total loss in a trial was assumed to be proportional to the mean difference of temperature between the water discharged and the air of the engine room, this latter temperature being always taken from a thermometer standing in a definite position. A quantity R, representing the loss by radiation per trial per unit difference of temperature between the brake and the air was deter-

mined, so as to make the value of the equivalent given by the heavy trials alone equal to that given by the light trials alone.

This quantity varied from 36·86, in trials made with the brass of the brake exposed directly to the air, to 7·98 in trials made with the brake covered with loose cotton lagging.

(2) *Loss by conduction along the engine shaft.*

This was assumed to vary as the difference in the readings of two thermometers, placed, the one on the stuffing-box making the joint between the brake and the shaft, and the other on the lower brass of one of the main shaft bearings distant some $2\frac{3}{4}$ inches from the cover of the stuffing-box.

From the first 42 accepted trials this loss was calculated to be 12 thermal units per unit difference of temperature between stuffing-box and bearing per trial. The conical brass bushes forming the bearings of the brake itself were lubricated by forcing a stream of ice-cold water from the supply pipe, through each into the brake. Consequently, by regulating the amount of this water supplied to the stuffing-box, I had a very delicate control over the temperature gradient along the shaft. In the later trials I endeavoured to make this gradient zero, and thus cut out altogether any loss of heat by conduction.

(3) *Loss by leakage of water from the envelope formed by the supply and discharge pipes, the brake and the tank.*

The only leakage of consequence was that which might occur after the water entered the brake.

The brake itself had three working joints.

1st.—The stuffing-box on the engine shaft.

2nd.—The smaller stuffing-box through which passed a pin, making the connection between the shaft and the revolution counter.

3rd.—The regulating valve controlling the flow of water from the brake.

Some leakage occasionally occurred at the shaft stuffing-box. This was all caught in the later trials, and the heat generated in it per lb. was assumed to vary as difference of the temperatures of the stuffing-box cover and of the water in the supply pipe.

The second stuffing-box worked absolutely dry. Leakage always occurred at the regulating cock. This consisted of hot water, and a special device was made to catch it so as to ensure no loss by evaporation. The water thus caught was weighed with the main stream which had entered the tank, and credited with the full rise of temperature between the supply and discharge pipes. A fourth working joint in the envelope was at the point where the discharge pipe emptied itself into the tank. A determination of the loss that might occur in the end of the discharge pipe and tank was made by pumping the water continuously for an hour up from the tank, and back to it through the discharge pipe, which had been disconnected from the brake for the purpose. The loss was found to be very nearly ¼lb. in all trials, and, since it would be eliminated almost entirely on the difference of heat, it was neglected altogether.

A further correction was often necessary to the apparent heat obtained on account of the change in temperature of the brake itself, together with its water content, during a trial. The amount of contained water varied with the speed of revolution. Accordingly a curve was plotted giving, for different speeds and loads, the thermal equivalents of the brake and contents.

At 300 revs. and 1200 ft.-lbs. this was 57·6 lbs. of water.
„ „ „ 600 „ „ 54·6 „ .

The gain or loss of heat by the brake was added to or subtracted from the apparent heat obtained.

4. *The method of conducting the experiments was as follows:*

During the progress of the experiments I had the assistance of two men and a boy. The first of the men had to keep the boiler pressure constant and attend generally to the needs of the engine. The second had charge of a small hand-brake, by means of which the speed of revolution could be delicately adjusted, and further, it was his duty to keep a constant pressure of air in a receiver which was in direct communication with the inner surfaces of the water vortices formed in the brake. This receiver had been attached to the brake in place of a former free communication with the atmosphere, which would have allowed the water in the brake to boil away when the temperature rose to 212°F. The boy's time was fully occupied in charging the ice-cooler with ice.

In the last series of experiments three similar trials, of 62 minutes duration each, were made per day, the engine never being stopped after the start till all three trials were completed. Consequently, what is said below as to the starting of the engine, only refers to the first trial made on any day.

I. The pump and engine were started simultaneously, the brake being therefore supplied with a stream of water from the ice-cooler. The brake then automatically adjusted the amount of the contained water till the load floated steadily clear of the floor. The engine speed was then adjusted to the requisite point, viz., 300 revolutions per minute, as indicated by a speed gauge.

II. The temperature of discharge of the water then rose more or less quickly, on account of the work done on it in the brake. By adjusting the regulating valve in the supply pipe, the discharge temperature finally remained steady at about 212°F. The water supply to the stuffing-box was also regulated so as to get the desired difference

of temperature between the brake and the adjacent shaft-bearing. These adjustments took from a quarter to half an hour, and, when completed, the engine was allowed to run for some half-hour longer to ensure a steady condition being attained. The condensing water had also, in the meantime, been adjusted till the water issuing from the discharge pipe had the required temperature.

III. Readings were then taken of :—

(*a*) the revolution counter,

(*b*) the weight of the empty tank and its cover.

IV. When a steady condition was reached, on a signal being given, the connection of the revolution counter with the engine shaft was made simultaneously with the pulling over, by a system of links, of the two-way tipping switch, and the stream of water which had hitherto been flowing to waste was thus diverted into the tank.

The vessels used to catch the leakage from the stuffing-box and regulating cock were placed under their respective drain pipes.

The speed of the engine, as indicated by the gauge, was read on the signal being given, and as soon as possible afterwards an observation was made of the temperature in the discharge pipe.

V. At intervals of 2 minutes, 30 observations were then taken of the temperatures of supply and discharge of the water to and from the brake, and also at each of these intervals a note was made of the indication of the speed gauge.

At intervals of 4 minutes, 15 observations were made of the thermometer registering the temperature of the room ; and at intervals of 8 minutes readings were taken of the two thermometers in the stuffing-box and on the main bearing.

VI. When 62 minutes had elapsed, the counter was disengaged from the shaft, and at the same time the stream of water was again diverted to waste. The drain pipes from the stuffing-box and regulating cock were removed from their respective vessels. Readings were taken of the speed indicator and of the temperature of discharge.

VII. Fresh observations were made of:—

(*a*) the reading of the revolution counter,

(*b*) the weight of the tank and water received during the trial, to which had been added the water caught from the regulating cock.

A record was also made of:—

(*c*) the weight of water which had been caught at the stuffing-box.

5. *The observations were then reduced as follows:*

Let T_1 = mean temperature of water supplied to the brake,
T_2 = " " " discharged from "
W_1 = weight of tank and contents before the trial,
W_2 = " " " after "
w = weight of water caught from stuffing-box,
t = rise of reading of the thermometer in the discharge pipe during the trial,
T = mean temperature of the stuffing-box cover,
T_3 = " " " lower brass of the main bearing,
T_4 = mean temperature of the air,
N_1 = reading of revolution counter before the trial,
N_2 = " " " after "
M = moment in ft.-lbs. carried by the brake.

Therefore we have for the total heat generated

$$H = (W_2 - W_1)(T_2 - T_1) + w(T_2 - T_1) + t.x + (T_2 - T_4)C + (T_3 - T_4)R.$$

where *t.x.* stands for the terminal correction to the heat due to change of temperature of the brake, and

C = conduction-constant per unit diff. of temperature.

R = radiation-constant " " "

Also the total work done

$$U = 2\pi(M + m)(N_2 - N_1),$$

where m = error of balance of the brake.

If the capitals H and U refer to trials with a large turning moment on the brake, and the small letters *h* and *u* refer to trials with a small turning moment, then for the value of the mean specific heat of water in mechanical units we have

$$K = \frac{U - u}{H - h}$$

The letter K is used here in preference to the usual notation J, since the constant obtained is not strictly the same as that determined by Joule and other experimenters; for it must be borne in mind that we are here dealing with the mean specific heat of water between the freezing and boiling points.

6. *The reliability of the measurements.*

I was personally responsible for every observation taken, with the exception of the two readings of the speed gauge taken at the beginning and end of each trial, and also for the checking of all the apparatus used in the research.

The measurements fall generally under two heads.

I.

The measurement of work.

This involved the balance of the brake, the length of the lever, the determination of the values of the weights used in loading the brake, and the counting of the revolutions.

(*a*) *Balancing the brake.*

This was an extremely difficult operation to perform, owing to the large amount of friction which occurred between the brake and the engine shaft. A number of experiments were made which shewed that the want of balance could not exceed ½ ft.-lb. This want of balance would make an error in the work calculated for each individual trial, but on the difference of work done in any two trials the error was completely eliminated if each had the same number of revolutions. Consequently, the speed of the engine was regulated to the end that the number of revolutions should be the same in any two trials which were afterwards to be compared.

Even with a difference of 300 revolutions, which was about the maximum difference, between the two trials, the error of ½ ft.-lb. in balance would make an error of less than 0·0015 per cent in the calculated difference of work. Further, since this error was a casual one, it was probable that it would cut out on the mean final result, and being so extremely small on any individual determination it has been neglected.

(*b*) *Length of the lever.*

This was determined by very careful observation to be 4ft. + 0·02in. when the engine was running under all the conditions which obtained in the trials. As in the preliminary calculations this length was given its nominal value of 4ft., the value of K obtained required a correction of + 0·042 per cent.

(*c*) *The weights used in loading the brake.*

These were cast iron plates weighing 25lbs. each. Their weights were determined to $\frac{1}{100}$lb., and in the later trials they were so arranged that no error could appear in the final result on account of the slight differences

which were found to exist between the weights. The extreme variation from 25lbs. was 0·04lbs.

(*d*) *The counting of the revolutions.*

This was done by means of a counter, which was pushed into gear with the shaft at the commencement of a trial, and disengaged at its close. The engagement was of such a character that the mean chance was that ¼ revolution was missed at the commencement of the trials, while at the end the counter stopped as soon as it was withdrawn from the shaft. The work obtained therefore needed a correction of

$$+\frac{\frac{1}{4}}{18000} = +\frac{1}{72000} = +0{\cdot}00001 \text{ nearly.}$$

This correction was added to the mean values of K derived from the trials.

II.

The measurement of heat.

This involved the calibration of the scale of the weighing machine, and the frequent determination of the index errors of the two thermometers used in the determination of the rise in temperature of the stream of water flowing through the brake.

(*a*) *The weighing machine.*

It was of vital importance that the same unit of mass should be used for the weighing machine scale and for the weights used on the brake. The scale of the machine was consequently checked against the 25lb. weights and *vice versâ*. By this means a series of corrections to $\frac{1}{100}$lb. was obtained for all readings, and, with the exception of casual errors occurring in any individual weighing, the determination of the mass of water may be taken as accurate to $\frac{1}{100}$lb.

(*b*) *The index errors of the thermometers.*

For the initial temperature thermometer this error was determined by immersing it in a mixture of crushed ice and water. In most of the trials this thermometer gave readings between 33° and 34°. On this interval the index correction was found to be correct when compared with a standard thermometer in the Physical Laboratory of the College. Higher up the scale a slightly larger negative correction to the readings was found to be necessary, and this correction was applied to the later trials when required.

The main accepted experiments lasted from February to July, 1896, and during that interval six determinations were made of the index error of this instrument.

The correction required by the readings fell from −0·48° on Feb. 5th to −0·52° on July 7th.

By the use of Regnault's steam tables, corrections were obtained to the indications of the thermometer used in the discharge pipe at the points 212°, 213·8°, and 215·6°, and also at lower temperatures when the barometric pressure permitted.

The corrections were obtained by immersing the thermometer in steam at these temperatures, the pressures being reduced directly from Regnault's table.

These pressures were measured to $\frac{1}{1000}$in. of mercury by means of a combined manometer and barometer specially constructed for the purpose.

The corrections obtained fell from +0·24 on February 8th to +0·04 on July 6th, 1896.

Both of these thermometers worked under a considerable pressure, and on that account a determination of the elevation in their readings, due to a known pressure, was made. This elevation I found, in the case of the thermometer (Q2) used in the supply pipe, to be 0·0072° per inch of mercury pressure, and for the thermometer

(P1) used in the discharge pipe the corresponding rise was 0·0066° per inch of mercury.

The pressures under which the initial temperature thermometer (Q2) worked were different, according to the load carried by the brake. Taking these varying pressures into account, a correction factor to be applied to the final result was obtained. Its value was (1 − 0·00037). After applying this correction it is extremely improbable that any error exceeding $\frac{1}{100}$°F., or one part in 18,000, can have existed in the calculated mean rise of temperature of the water in any trial.

7. *The main experiments.*

The trials were begun on Feb. 5th, 1896. The accepted trials were made in 11 different series, each series containing generally 3 pairs of heavy and light trials. Between each series, some slight alteration was made in the apparatus or method of working, all the alterations leading up to the methods finally adopted, and which have been described.

Series I.

Contained 4 pairs of trials, giving 4 separate determinations of K. This series differed from all that followed it in that the outer brass skin of the brake was exposed directly to the atmosphere, and consequently the radiation constant had the large value of 36·86.

The mean value of K obtained from the series was 777·81. The maximum value being 778·56 and the minimum 777·02. This series of trials has not been allowed any weight in the final result, because in some of the trials the necessary observations of the temperature gradient in the shaft were not taken, and, consequently, the conduction correction could only be approximated to by assuming this gradient the same in all the trials, since the supply of cold water to the stuffing-box on the shaft

was the same in all. This series, when compared with others that follow, was of use, in so far as it showed to some extent the limit of error involved in the method of eliminating the loss of heat by radiation.

The results obtained from the first series were so satisfactory that the lagging of the brake was at once proceeded with. This consisted of a layer of about 1½ inches of loose cotton covered with thick flannel.

Series II. to VII.

Contained trials Nos. 12 to 42. In trial No. 12 the lagging was evidently damp, and the results obtained were consequently rejected. Trials Nos. 24, 25, and 26 have not been reduced at all, because the load carried by the brake was 1244·12 ft.-lbs., and therefore the results were not readily comparable with the other heavy trials, which carried a load of 1200 ft.-lbs. In addition to this the tightness of the bottom regulating cock on the brake was so great, as to impede its motion by a moment of 30 ft.-lbs. about the engine shaft.

Series V., containing trials 27 to 32, also suffered under the latter defect, and have, therefore, been allowed no weight in the final result. The individual results do not differ materially from others which have been obtained, but the want of freedom of the brake was thought sufficient to condemn them.

The annexed table gives the maximum, minimum, and mean values of K given by these series.

	Number of Determinations	Values of K obtained		
		Maximum	Minimum	Mean.
Series II.	2	778·3	777·02	777·66
Series III.	3	779·46	776·63	777·94
Series V.	3	778·46	777·75	778·1
Series VI.	2	778·59	777·16	777·89
Series VII.	3	778·55	777·02	777·86

Omitting Series V. for the reasons mentioned, the mean value of K, obtained by dividing the sum of the differences of work in the above determinations by the corresponding sum of the differences of heat, is

$$K = 777{\cdot}85.$$

From this the greatest variation is less than 0·3 per cent in individual determinations, and for the means given by each series the greatest variation is less than 0·03 per cent.

Series VIII. and IX.

Differed from the last series considered in that the light trials only carried a moment of 400 ft.-lbs.

	Number of Determinations.	Values of K obtained.		
		Maximum.	Minimum.	Mean.
Series VIII.	2	778·47	778·07	778·27
Series IX.	3	778·54	777·78	778·22

Series X. and XI.

These trials were made in July, 1896, after the careful checking of the whole of the apparatus afresh. The results are appended.

	Number of Determinations.	Values of K obtained.		
		Maximum.	Minimum.	Mean.
Series X.	3	778·44	776·89	777·74
Series XI.	3	778·07	777·56	777·88

These trials were run under precisely similar conditions as to load, &c., as obtained in Series II. to VII.

The mean value obtained for the two Series was

$$K = 777{\cdot}85,$$

which happened to agree exactly with that given by the former set.

For the final value of K, the quantities given in the appended table were obtained :—

	Number of revolutions of shaft.	Work done.	Heat generated less losses due to terminals, conduction, &c.	Loss of heat by leakage of water.	Terminal correction to heat.	Difference of temperature between stuffing-box and bearing.	Difference of temperature between brake and air.	Corrected heat.
Means for 21 accepted heavy trials.	17817	134337403	171510	4	—1	—3·9	140·5	172685
Means for 23 accepted light trials.	17832	61355503	77710	1	—7	—5·4	141·5	78·867
Mean differences.	—15	72981900	93800	3	6	1·5	—1·	93818
	1	2	3	4	5	6	7	8

A value of K is obtained by dividing the difference of work in col. 2 by the uncorrected difference of heat in col. 3. This operation gives

$$K_1 = 778{\cdot}06.$$

This value, however, wants correcting on account of the quantities in cols. 1, 4, 5, 6, and 7.

(1) *Error in balance of brake.*

It has been shown that the difference of 15 revolutions in col. 1 will not, when the error of balance of the brake is considered, have any appreciable effect in the value of K_1 given above.

(2) *Loss of heat by leakage.*

In col. 4 this loss is given as 3 thermal units. The correction to K_1 is therefore $-\frac{3}{93800}$

$$= -0{\cdot}000032.$$

(3) *Terminal corrections to the heat.*

In col. 5 the difference of these corrections is given as 6 thermal units. The correction to K_1 is therefore $= -0{\cdot}000064$.

(4) *Loss of heat by conduction along the shaft.*

In col. 6 the difference of temperature between the brake and the adjacent bearing is $1{\cdot}5°$. The loss per $1°$ is 12 thermal units. The correction to K_1 is $= -0{\cdot}000192$.

(5) *Loss of heat by radiation.*

In col. 7 the difference of temperature between brake and air has the value $-1°$; assuming 9 for the constant of radiation the correction to K_1 becomes $= 0{\cdot}000096$.

The total correction factor required on account of the non-elimination of these casual errors is therefore

$$1 - 0{\cdot}000192.$$

Applying this factor we get

$$K_2 = K_1(1 - 0{\cdot}000192) = 778{\cdot}06\,(1 - 0{\cdot}000192) = 777{\cdot}91.$$

This value K_2 can also be obtained by dividing the difference of work in col. 2 by the difference of heat (corrected) in col. 8.

This value K_2 now requires a correction factor made up of a number of quantities which are dealt with below.

8. *Corrections to the mean value of K (777·91) given by the experiments.*

I. *Length of brake lever.*

This correction has been calculated to be 0·00042.

II. *Salts dissolved in Manchester water.*

These amount to 42·1 milligrammes per litre. Assuming their specific heat $= 0{\cdot}2$, the correction required is 0·00003.

III. *Air dissolved in the water used in the trials.*

This had an effect in raising the apparent specific heat of the water, on account of the bubbles of air expelled being saturated with vapour at 212°F. I made experiments to determine the volume of the bubbles, and from the data so obtained a correction was calculated at −0·00021.

IV. *Reduction of the weighings to vacuo.*

Bearing in mind that the density of the air affected equally the cast iron load on the brake, and also the rider weights of the weighing machine, this correction becomes −0·00120.

V. *Varying specific heat of the water.*

If Regnault's formula for the specific heat of water were accepted, the value of K obtained would require a correction of −0·00070, introduced by the fact that the initial temperature of the water was never exactly 32°F., as assumed in the specific heat used in the calculations.

So little is known of the true value of the specific heat at any temperature that this correction has not been applied.

VI. *Correction due to pressures on thermometer bulbs.*

This has been stated to be −0·00037.

VII. *Correction due to loss of head in stream of water between supply and discharge pipes.*

A certain amount of heat would be generated by this loss of potential energy.

The correction required is +0·00007.

VIII. *Engagement of revolution counter.*

This has been already given = +0·00001.

Adding all these corrections together, we get as a final correction factor

1 − 0·00125.

9. *Conclusions.*

We have, therefore, for the corrected value of the specific heat of water, expressed in mechanical units, measured at Manchester,

776·94 ;

at Greenwich, correcting for gravity,

777·07 ;

and in latitude 45°, at sea level,

777·53 ;

or, in metre-grammes, this last value becomes

426·58,

as the equivalent of the mean value of the Centigrade unit of heat.

In absolute C.G.S. units this becomes

41,832,000 ergs.

Manchester Memoirs, Vol. xlii. (1898), *No.* 7.

VII. On the Instantaneous Pressures produced on the Collision of Two Explosion Waves.

By R. H. JONES, B.Sc.,

AND

J. BOWER, B.Sc.

[Communicated by Professor H. B. Dixon, F.R.S.]

Received and read February 8th, 1898.

A paper, the latter portion of which treated upon this subject, was brought before the Society in 1894 by Dixon and Cain; but, owing to knowledge attained since that time by the former investigator in conjunction with ourselves, some doubt has been thrown on the significance of the numbers then obtained.

At a recent meeting of the Society, Professor Dixon brought before your notice several photographs taken in order to gain information concerning the "Nature of Flame in Explosion." Among the photographs were several shewing that the effect of a junction in the apparatus is to check the rate of explosion and to diminish the luminosity very materially, the explosion wave only recouping itself after traversing the explosion tube for some six or eight inches beyond the junction.

This we discovered by photographing the flash on a sensitive film fastened to a rapidly-revolving wheel.

The apparatus consists essentially of a flat-rimmed

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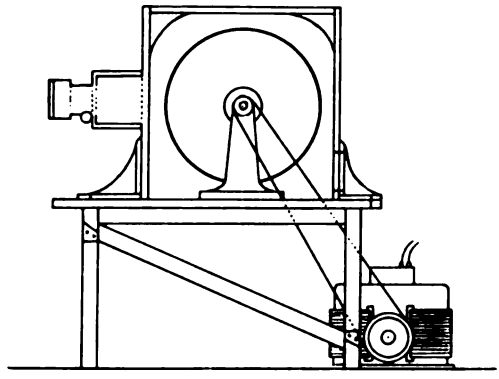
tinned-iron wheel, capable of being rapidly rotated about a horizontal axis, the rim upon which the photographic film is placed being 1½in. wide.



The lenses of the camera are arranged so that an image of the explosion tube placed horizontally and parallel to the axis of the wheel may be focussed on the rim. Since the explosion travels along the glass tube horizontally and the wheel is revolving in a vertical plane, the image of the flash on the film appears as a line inclined to the horizontal, the sine of this angle varying inversely as the velocity of the flash, provided the rate of the wheel is constant.

A photograph of the flash immediately after it has passed an imperfect junction in the apparatus is shown in *fig. 1.* The explosion wave has been partially checked, and the point of redetermination is clearly visible.

The second figure shows the collision of two partially-destroyed explosion waves before they have had time to recuperate.

In the case illustrated by the third figure, the explosion wave has been alternately determined and checked two or three times. This was brought about by having three strong glass tubes placed horizontally and parallel

to one another, fastened together by lead bends and caps which fitted over the glass, the mixture being fired in the uppermost tube.

What we required was a junction of lead pipe to glass tubing, both the lead and glass having an internal bore of ¼in., but having different external diameters—the lead ⅜in., and the glass ¾in. The mode of joining in these cases where a stoppage occurred was to take a short piece of lead piping, which just slipped over the glass tubing, and to beat down one end until the bore at that end was only ¼in.; this was then soldered to the lead piping of ¼in. internal diameter, a short piece of rubber tubing was drawn over the end of the glass tubing, and this was finally thrust into the lead cap. These junctions were not quite rigid, and the ends of the tubes not exactly flush.

The pictures given show clearly the partial stoppage of the explosion wave at such a joint, the point of redetermination being indicated by a definite and increased speed of combustion, represented by the straight and intensely luminous line as distinct from the curved and less luminous line of the recouping period.

Further, a new and very luminous wave is observed starting from the point of redetermination of the explosion wave proper, and travelling in the opposite direction with a speed almost, if not quite, equal to that of the explosion wave itself.

The point, however, bearing most directly on Dixon and Cain's paper is this—that tubes which stood the pressure of the explosion wave itself, almost invariably broke at this point of redetermination.

Thus, in their experiments, they might really be measuring, not the pressure of the explosion wave, but this greater pressure always associated with the re-institution of the wave after a partial stoppage. The figures obtained forced them to the conclusion that there was no

to make sure that one explosion did not tend to diminish its strength, and it was found that if a tube stood an explosion once it would remain intact after any number of explosions, and yet would be shattered to fragments by the pressure produced by impact of two explosion waves.

The samples of tube which were hydraulically tested gave the following results for breaking pressures :—

1. Tubes which broke *one* way—

$$\left.\begin{matrix}840\text{lbs. per sq. in.}\\ 896\text{lbs. }\quad\text{„}\end{matrix}\right\}\text{Mean } 868\text{lbs.} = 58 \text{ atmos.}$$

2. Tubes which stood one way, but broke with two waves meeting—

$$\left.\begin{matrix}1000\text{lbs. per sq. in.}\\ 1232\text{lbs. }\quad\text{„}\\ 1120\text{lbs. }\quad\text{„}\end{matrix}\right\}\text{Mean } 1117\text{lbs.} = 75 \text{ atmos.}$$

3. Tube which stood both ways—

$$1344\text{lbs.} = 90 \text{ atmos.}$$

Hence we have the increase of pressure on collision of two explosion waves clearly demonstrated.

Comparison of these numbers with those of the earlier paper will shew a considerable difference.

As previously stated, the higher numbers obtained by Dixon and Cain are possibly due to the fact that their tubes were fractured, not by the explosion wave, but by the greater pressure always evident at the point of redetermination of the wave after a partial stoppage. We are now conducting experiments with other mixtures of gases.

The phenomenon of the collision of two true explosion waves is shown in *fig. 4*.

The photograph shews that the junctions in the apparatus produced no disturbing effect on the explosion wave.

Two rebound waves start from the point of collision in opposite directions along the tube. These are sound waves, made luminous by passing through the still heated gases. A comparison of this photograph, where the true

explosion waves meet, with that of the collision of the waves whilst in the recouping period after a partial stoppage (see *fig.* 2), shews that, in the former case, the rebound waves are less luminous and travel much more slowly than the explosion waves; whilst, in the latter case, the rebound waves are more luminous and travel faster than the recouping explosion waves.

A sound wave, similar to those obtained on the collision of two explosion waves, is produced when an explosion takes place in a glass tube closed at one end, rebounding from the end surface and travelling back along the tube.

The fifth figure gives an illustration of the phenomenon just mentioned. Notice that the angle which the rebound wave makes with the horizontal diminishes, thus indicating that the rate becomes faster. The dark vertical line, used for purposes of measurement, is caused by a small black band placed on the explosion tube.

Comparison of the rate of this rebound with that of each of the rebounds produced when two explosion waves meet shows the former to be slower.

The ratio of the two rates is about 10 to 13.

Thus we have indirect evidence of the increase of pressure when two explosion waves come into collision.

This is again confirmed by the increased intensity and longer duration of the light which the photograph displays at the point of collision.

The evidence from the actual measurements, the rates of the rebounds, and the luminosity, taken together, seem to establish beyond a doubt the increase of pressure on collision of two explosion waves.

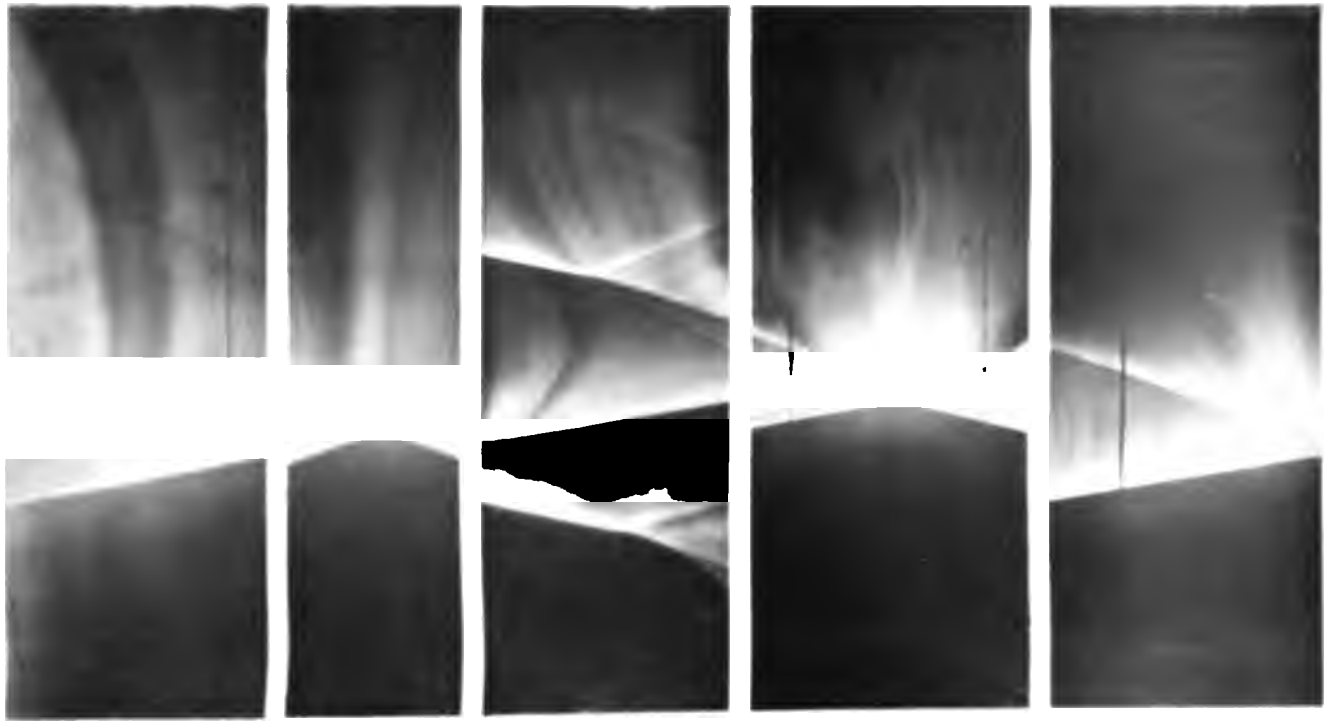


Fig 1 Fig 2 Fig 3. Fig 4 Fig 5

COLLISION OF EXPLOSION WAVES

Manchester Memoirs, *Vol. xlii.* (1898), *No.* 8.

VIII. On a General Method of determining the Form of the Velocity-Potential of Fluid-Motion in Two Dimensions across a Channel with Straight Sides.

By R. F. GWYTHER, M.A.

Received and read January 11th, 1898.

In a paper* on the permanence of Mathematical Forms of the expressions for physical quantities, I have pointed out that the forms of the general equations in applied mathematics are necessarily limited by purely mathematical considerations, and, to that extent, independent of the physical assumptions on which they may have been originally based.

The present paper may be regarded as a continuation of that paper, but dealing with the limitations imposed by the same considerations upon the possible forms of the solutions of the general equations rather than upon the forms of the equations themselves.

It will appear in the development of the subject, that when the form of solution is limited by the considerations proper to a problem, the process of change of coordinate axes, or of resolution of velocities, &c., will be notably simplified in consequence.

It is, of course, necessary to select an illustration only of the method proposed, partly because the conditions in different problems are so varied, and partly in order to make the character of the method clear by making the conditions definite.

For these reasons, I have selected, as a general

* *Manchester Memoirs*, Vol. IX, 4th series, 1895, p. 119.

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problem which has well defined conditions, the irrotational motion of a fluid in two dimensions across a channel with straight sides.

THE FORM OF THE VELOCITY-POTENTIAL.

With the modification of the usual notation adopted in Lamb's *Hydrodynamics*, write

$$-\phi - i\psi = f(x + iy),$$

so that

$$u - iv = f'(x + iy).$$

The function $f(x+iy)$ will, in general, contain as arguments the measure and direction, relative to the axes, of gravitation, and the *coordinates*, whatever they may be, of the lines bounding the fluid. As it is assumed that these bounding lines are straight, these arguments may be taken to be g and γ, p_1 and β_1, p_2 and β_2, etc., where p and β are the coordinates of a straight line.

The origin and axes of coordinates are to be taken arbitrarily, and the principle which is fundamental in the method of this paper is that with any system of boundaries the function $f(x+iy)$ will enjoy a permanence of form for any change in position or direction of the coordinate axes, or, stated analytically, must be a covariant of the system,

$$x + iy,\ t,\ g,\ \gamma,\ p_1,\ p_2,\ \ldots\ldots\ ,\ \beta_1,\ \beta_2 \ldots\ldots\ ,$$

or of

$$x + iy,\ t,\ g,\ \gamma,\ p_1,\ p_2, \ldots\ldots\ ,\ \beta_1 - \gamma,\ \beta_2 - \gamma, \ldots\ldots ,$$

where γ has been selected as the angle by which to orient the system of coordinates in space.

In considering the conditions for covariancy under a change of axes, the letters x, y, γ, p, β, will still be retained to mean the quantities relative to the new axes corresponding to those they previously indicated relative to the old axes; after the conditions have been found it will be useful to drop this convention with results which will be seen later.

Employing this convention for the present, it is easy to see that if the axes are turned through an angle α, retaining the origin, there is no change in $\beta-\gamma$, but $x+iy$ is replaced by $(x+iy)e^{i\alpha}$, and γ by $\gamma+\alpha$. We must therefore, take the arguments of the function to be

$$(x+iy)e^{-i\gamma},\ t,\ \xi,\ \rho_1,\ \rho_2,\ \ldots\ldots,\ \beta_1-\gamma,\ \beta_2-\gamma,\ \ldots\ldots.$$

Next, if we give the coordinate axes an arbitrary infinitesimal displacement of translation, the analytical conditions for covariancy are extremely simple, and it will be sufficient to state the results as they affect the mode of entrance of the several arguments into $f(x+iy)$.

These are that $\rho_1, \rho_2, \ldots\ldots$ will only enter the function in the form

$$\rho_1 e^{i(\beta_1-\gamma)} - \rho_2 e^{i(\beta_1-\gamma)}, \text{ etc.},$$

and that $x+iy$ will only enter in the form

$$(x+iy)e^{-i\gamma} - i\{\rho_1 e^{i(\beta_1-\gamma)} - \rho_2 e^{i(\beta_1-\gamma)}\}/\sin(\beta_1-\beta_2), \text{ etc.}$$

For brevity, write q_1 for

$$\rho_1 e^{i(\beta_1-\gamma)} - \rho_2 e^{i(\beta_1-\gamma)}, \text{ etc.},$$

then the arguments of $f(x+iy)$ may be taken as

$$(x+iy)e^{-i\gamma} - iq_1/\sin(\beta_1-\beta_2),\ t,\ \xi,\ q_1,\ \ldots\ldots,\ \beta_1-\gamma,\ \beta_2-\gamma\ldots\ldots$$

In writing them in this way an arbitrary preference has been given to the boundaries of subscripts 1 and 2, but in any case to which this method may be applied it appears probable that such a choice would ultimately be made, and its introduction here in no way affects the generality of the results.

This completes the conditions which the permanence of form demands.

With the form of the function limited in this way, and still written $f(x+iy)$, we deduce

$$u - iv = e^{-i\gamma} f(x+iy),$$

which can easily be seen to satisfy the requirements which have here been developed.

In the case of a channel bounded by 2, 3, etc., sides we have found what arguments may enter into $f(x+iy)$, but, of course, from general considerations we cannot learn more of the manner in which they enter the function. We proceed to deal with other matters with regard to which general conclusions can be arrived at.

SIMPLIFICATION OF RESULTS CONSEQUENT ON A CHANGE OF AXES.

In this process a very obvious advantage resulting from the stipulation that $f(x+iy)$ shall have its general covariant form becomes apparent.

The convention which has been adhered to up to the present that γ, β_1, β_2,....., (as well as $x+iy$) shall, after a change of axes, represent magnitudes measured from the new axes, will now be dropped, and in the case of the angles (but not of $x+iy$) will be considered to retain the reference to the original axes. This will, of course, make no change in $\beta-\gamma$, but in γ only.

The change necessary, when the axes are turned through an angle a, will merely be to write $\gamma-a$ in place of γ, or sometimes more simply, to write $(x+iy)e^{ia}$ in place of $(x+iy)$.

CONDITION AT A BOUNDARY LINE.

Supposing now that a convenient system of axes has been chosen in any case, and that the angles are given relative to that system, it becomes necessary to express the condition that there is no flow over the boundary whose coordinates are β, β, or that ψ is constant along that boundary. Changing to an axis of y parallel to this bounding line, from the last paragraph it appears that all that is necessary to ensure this condition, is to write

$(\rho+iy)e^{i\beta}$ in place of $x+iy$ and to stipulate that the imaginary part of $f(x+iy)$ shall, in consequence, become constant.

The corresponding condition affecting the velocity may be dealt with in the same manner, when that is preferable to dealing with ψ.

Other modes of orienting the system.

Hitherto. the orientation of the system in space has been effected by orienting the axes by means of γ relative to the vertical, and the system relative to the axes by β's. This is, of course, an arbitrary arrangement, but it is perhaps the least arbitrary among such arrangements, and it has secured a formal unity in the expressions without interfering with the generality of the results.

In any particular case, however, the horizontal and vertical will probably be taken as axes, and all that is then necessary is to orient the system in the most convenient method with reference to the axes, and this may sometimes best be done by using some line specially convenient for the purpose which need not be the vertical.

In illustration of this, we may take the general case of transverse motion of a fluid within a space bounded by two intersecting lines.

Most symmetrically, the system may be oriented by the position of the bisector of the angle between these lines, and the shape of the space containing the fluid determined by the semi-angle at the apex.

It would also be convenient to take the origin at the apex. We should then replace γ by $(\beta_0+\beta_1)/2$, and get in the first place

$$-\phi-n\psi=f\{(x+iy)e^{-n(\beta_1+\beta_0)/2}\}$$

with the boundary conditions that the imaginary parts of

$$f\{iye^{+n(\beta_1-\beta_0)/2}\}$$

may be constant.

If we write λ for the angle the bisector makes with the axis of x, and μ for the semi-angle at the apex. These expressions become

$$f\{(x+iy)e^{-i\lambda}\} \text{ and } f\{ye^{\pm i\mu}\}$$

respectively, and λ and μ as representatives of such quantities as $\beta_1-\gamma$, $\beta_2-\gamma$, may freely enter the function $f(x+iy)$.

It is easy to verify that the known cases of transverse oscillations in such a space (Lamb's *Hydrodynamics*, p. 426) where $\lambda=\frac{\pi}{2}$ and $\mu=\frac{\pi}{4}$ or $\frac{\pi}{3}$, are in accordance with the expressions here given.

The main difficulty in finding solutions to suit actual cases of fluid motion is the condition, not here dealt with, relating to the pressure at the surface of the fluid, and no new solution is here offered. The very suggestive form arrived at in the expression $f\{(x+iy)e^{-i\lambda}\}$ is perhaps worthy of notice.

Manchester Memoirs, *Vol. xlii.* (1898), *No.* 9.

IX. On the Velocity of Sound in a Tube, as affected by the Elasticity of the Walls.

By Prof. HORACE LAMB, M.A., F.R.S.

Received and read March 8th, 1898.

Reference having been made to this subject in the course of a recent discussion in the Society, it occurred to the writer that some results of interest might be obtained without much trouble by applying the known theory of the deformation of a *thin* cylindrical tube. It soon appeared that although in the case of air-waves in a glass or metal tube the effect would be quite insignificant, yet in the case of such a tube filled with *water* (or other liquid) the velocity of sound-waves in the fluid might be very appreciably reduced. This had indeed been predicted long ago by Helmholtz,* and assigned by him as the true explanation of the diminution observed in some experiments of Wertheim. On further looking into the literature of the subject, the author found that the problem had been treated mathematically by Korteweg in 1878.† As the investigation given below in § 1 follows a somewhat different plan, and embraces one or two collateral problems of interest, the writer ventures to submit it to the Society, although on the main question it does little more than confirm the results obtained in the paper cited.

When the assumption that the thickness of the tube is small compared with the radius is abandoned, the problem becomes much more difficult. The method of

* *Berl. Berichte der Physik*, t. iv.; *Ges. Abh.*, t. i., p. 246.

† *Wied. Ann.*, t. v., p. 526. This paper gives references to the more recent experimental investigations on the subject by Kundt and Dvorak.

July 13th, 1898.

applying the general equations of elasticity to this case is indicated in § 3. In order to diminish to some extent the complexity of the analysis, attention has been directed mainly to the case where the external radius is infinite. This has, moreover, a special interest as forming the opposite extreme to the circumstances considered in the previous part of the paper. Even here the final equation for determining the wave-velocity is of a somewhat unmanageable character; but it leads to a very simple result when the wave-length is very great compared with the circumference of the tube. It is to be remarked, indeed, that the more definite results obtained throughout this paper are, as a rule, of the nature of limiting forms which are approximated to more closely the greater the wave-length. In some of the experiments on the subject, the ratio of the wave-length to the circumference of the tube cannot be said to be very great; a correction on this account, when the ratio is moderately large, might be investigated without much difficulty.

1. Let the axis of x be taken along the axis of the tube, whose thickness (h) will for the present be assumed to be small compared with the radius (a). In the deformations to be considered, the displacement of any point of the wall will be in a plane through the axis, and if u and w denote its components in the directions of the generating line and of the radius, respectively, these quantities will be functions of x and t only. The linear extensions in the tangent plane, along and perpendicular to the generating line, will be du/dx and w/a, respectively. Hence if σ denote Poisson's ratio (of lateral contraction to longitudinal extension in a bar of the same material), the tensions called into play in these two directions will be

$$P = Bh\left(\frac{du}{dx} + \sigma\frac{w}{a}\right), \quad Q = Bh\left(\frac{w}{a} + \sigma\frac{du}{dx}\right) \quad . \quad . \quad (1)^*,$$

* See *Proc. Lond. Math. Soc.*, t. xxi., pp. 137, 138 (1890.)

where

$$B = \frac{4(\lambda+\mu)\mu}{\lambda+2\mu} \quad . \quad . \quad . \quad . \quad (2),$$

the elastic constants λ and μ being those of Lamé, viz. μ is the rigidity, and λ is a constant such that $\lambda+\frac{2}{3}\mu$ measures the elasticity of volume. In terms of the same quantities, we have

$$\sigma = \frac{\lambda}{2(\lambda+\mu)} \quad . \quad . \quad . \quad (3).$$

If ρ be the volume-density of the material of the wall, the equations of motion of the tube will be

$$\rho h \frac{d^2u}{dt^2} = \frac{dP}{dx}, \qquad \rho h \frac{d^2w}{dt^2} = p - \frac{Q}{a} \quad . \quad (4),^*$$

where p denotes the excess of pressure on the inner surface. Substituting from (1) in (4) we obtain

$$\left.\begin{aligned} \frac{d^2u}{dt^2} &= \frac{B}{\rho}\left(\frac{d^2u}{dx^2} + \frac{\sigma}{a}\frac{dw}{dx}\right), \\ \frac{d^2w}{dt^2} &= \frac{p}{h\rho} - \frac{B}{\rho}\left(\frac{\sigma}{a}\frac{du}{dx} + \frac{w}{a^2}\right) \end{aligned}\right\} \quad . \quad . \quad (5).$$

If we now assume that u, w, and p all vary as

$$e^{imx+nt},$$

we have

$$\left.\begin{aligned} \left(c^2 - \frac{B}{\rho}\right)u + \frac{i\sigma}{ma}\frac{B}{\rho}w &= 0, \\ -\frac{i\sigma}{ma}\frac{B}{\rho}u + \left(c^2 - \frac{1}{m^2a^2}\frac{B}{\rho}\right)w &= -\frac{p}{m^2h\rho} \end{aligned}\right\} \quad . \quad (6).$$

Here m is a constant such that $2\pi m$ is the wave-length; and c is the corresponding wave-velocity.

It will tend to make the subsequent results more intelligible if we recall the known solutions of these equations when $p=0$. The formula (6) then gives, on eliminating the ratio $u:w$,

$$c^4 - \left(1 + \frac{1}{m^2a^2}\right)\frac{B}{\rho}c^2 + \frac{1}{m^2a^2}\left(\frac{\sigma^2}{}\right)\left(\frac{B}{\rho}\right)^2 = 0 \quad . \quad . \quad (7),$$

* The flexural terms are here omitted. They are quite unimportant unless the wave-length of the disturbance be very small.

a quadratic in c^2. If, as is assumed throughout, the wave-length be large compared with the circumference of the tube, m^2a^2 will be a small fraction, and the roots of (7) will be approximately

$$c^2 = (1 - \sigma^2)\frac{B}{\rho} = \frac{E}{\rho} \quad . \quad . \quad . \quad (8),$$

where E denotes Young's modulus, and

$$c^2 = \frac{1}{m^2a^2}\frac{B}{\rho} \quad . \quad . \quad . \quad (9),$$

respectively. In the case of (8) we have, by the former of equations (6),

$$w/u = -i\sigma ma \quad . \quad . \quad . \quad (10),$$

This ratio is therefore small, and the vibrations are mainly longitudinal. The wave-velocity given by (8) is, in fact, that of longitudinal vibrations in a bar. If we continue the approximation, we find, in place of (8),

$$c^2 = (1 - \sigma^2m^2a^2)\frac{E}{\rho} \quad . \quad . \quad . \quad (11).$$

On the other hand, the solution (9) makes

$$u/w = -i\sigma ma \quad . \quad . \quad . \quad (12),$$

so that the vibrations are chiefly radial. The corresponding type of motion is, indeed, best described as a radial vibration, with a very gradual variation of phase as we pass along the tube; and the result is best expressed in terms of the "speed." Thus if we put $n = mc$, so that $n/2\pi$ measures the frequency of the vibrations, we have

$$n^2 = \frac{B}{\rho a^2} \quad . \quad . \quad . \quad . \quad (13)\ *$$

The next approximation gives

$$n^2 = (1 + \sigma^2m^2a^2)\frac{B}{\rho a^2} \quad . \quad . \quad . \quad (14).$$

* The results (8) and (9) are given by Love, *Theory of Elasticity*, t. ii., p. 259.

Let us now suppose that the tube contains an elastic fluid of density ρ_o. The pressure p is subject to an equation of the form

$$\frac{d^2p}{dt^2} = c_o^2\left(\frac{d^2p}{dx^2} + \frac{d^2p}{dr^2} + \frac{1}{r}\frac{dp}{dr}\right) \quad . \quad . \quad (15),$$

where r denotes the distance from the axis, and c_o is the velocity of waves of expansion in an unlimited mass of the fluid; viz., if we denote by κ the cubical elasticity of the fluid, we have

$$c_o^2 = \frac{\kappa}{\rho_o} \quad . \quad . \quad . \quad . \quad (16).$$

If

$$p \propto e^{i m(ct+z)},$$

(15) reduces to the form

$$\frac{d^2p}{dr^2} + \frac{1}{r}\frac{dp}{dr} - \nu^2 p = 0 \quad . \quad . \quad (17),$$

where

$$\nu^2 = m^2\left(1 - \frac{c^2}{c_o^2}\right) \quad . \quad . \quad . \quad (18).$$

The solution of (17) which is finite for $r=0$ is

$$p = CI_o(\nu r) \quad . \quad . \quad . \quad (19),$$

where the function I_o is defined by

$$I_o(z) = 1 + \frac{z^2}{2^2} + \frac{z^4}{2^2.4^2} + \ldots \quad . \quad (20).$$

Now, from the hydrodynamical equation

$$\rho_o\frac{d^2w}{dt^2} = -\left[\frac{dp}{dr}\right]_{r=a} \quad . \quad . \quad . \quad (21),$$

we have

$$m^2c^2\rho_o w = \gamma CI_o'(\nu a) \quad (22),$$

whence, for the value of p to be substituted in (6),

$$p = m^2c^2\rho_o a\,\frac{I_o(\nu a)}{\nu a I_o'(\nu a)}\,.\,w \quad . \quad . \quad (23).$$

The complete solution of our problem involves the determination of *three* classes of vibrations; viz. (I) the sound-waves in the fluid as modified by the yielding of the

tube, (II) the longitudinal vibrations of the tube-wall as modified (very slightly) by the presence of the fluid, and (III) the radial vibrations of the system.

In the cases (I) and (II), c^2 is comparable either with c_0^2 or with B/ρ, and for sufficiently long waves νa will be a small quantity. The formula (23) then reduces to

$$p = \frac{2m^2c^2\rho_0}{\nu^2 a}w \quad . \quad . \quad . \quad (24),$$

approximately. If we make this substitution in (6), and then eliminate the ratio u/w, we obtain

$$\left(c^2 - \frac{B}{\rho}\right)\left\{\left(1 + \frac{2\rho_0}{\nu^2 a h \rho}\right)c^2 - \frac{1}{m^2a^2}\frac{B}{\rho}\right\} - \frac{\sigma^2}{m^2a^2}\left(\frac{B}{\rho}\right)^2 = 0 \quad . \quad (25).$$

If we substitute the value of ν^2 from (18), this may be put in the form

$$(c^2 - c_0^2)\left\{c^4 - \left(1 + \frac{1}{m^2a^2}\right)\frac{B}{\rho}c^2 + \frac{1-\sigma^2}{m^2a^2}\left(\frac{B}{\rho}\right)^2\right\} - \frac{2\rho_0 a}{\rho h}\frac{1}{m^2a^2}c_0^2c^2\left(c^2 - \frac{B}{\rho}\right) = 0 \quad . \quad (26).$$

This is a cubic in c^2, but we are only concerned with the two smaller roots.

For very long waves, one root is very great, and the remaining pair are given by the quadratic

$$(c^2 - c_0^2)\left\{(1-\sigma^2)\frac{B}{\rho} - c^2\right\} = \frac{2a\kappa}{hB}c^2\left(c^2 - \frac{B}{\rho}\right) \quad . \quad (27),$$

where κ has been written for $\rho_0 c_0^2$. In the case of a gas enclosed in a metal or glass tube, the right hand side of (27) may be neglected, owing to the excessive smallness of the ratio κ/B.* The roots of (27) are then c_0^2 and E/ρ, the mutual influence of the vibrations of the fluid and of the tube being quite insensible.

In the case of a liquid, however, the fraction $2a\kappa/hB$ may well have an appreciable, and even a considerable value, and the alteration of the wave-velocity in the fluid

* Its value for air and glass is about $2{\cdot}34 \times 10^{-6}$.

may be important. It is easily seen that the quadratic (27) has in all cases two positive roots. If (as we shall generally suppose) c_0^2 is less than $E\rho$, one root will lie between 0 and c_0^2, and the other between $E\rho$ and $B\rho$. The former determines the velocity of waves in the liquid, as diminished by the elastic yielding of the tube; the latter determines the velocity of longitudinal waves in the tube-wall, as increased by the reaction of the enclosed fluid. If (on the other hand) c_0^2 were greater than $E\rho$, one root of (27) would lie between 0 and $E\rho$, and the second root between c_0^2 and $B\rho$. An extreme instance of this is afforded by water in an india-rubber tube; the fraction $2a\kappa/hB$ is then large, and the two values of c are found to be

$$(hE\ 2a\rho_0)^{\frac{1}{2}} \quad \text{and} \quad (B\rho)^{\frac{1}{2}},$$

approximately. The former of these agrees with the velocity of "pulse-waves" as determined theoretically by Résal.*

If σ were zero for the substance of the tube, the constants B and E would be identical, and one solution of (27) would be $c^2 = B\rho$, it being otherwise evident that the longitudinal vibrations of the tube would be entirely unaffected by the fluid. Moreover, the difference between B and E is for most solids a small fraction of either. Hence the velocity of longitudinal waves in the tube, which lies (as we have seen) between the limits $E\rho^{\frac{1}{2}}$ and $B\rho^{\frac{1}{2}}$, will not as a rule be more than slightly affected by the liquid. On the other hand, since the product of the roots of (27) is equal to

$$\frac{c_0^2 E\rho}{1 + 2a_1 hB^2},$$

it appears that the lower root, which determines the wave-velocity in the fluid, must lie between the limits

$$\frac{1-\sigma^2}{1 + 2a_1 hB \cdot c_0^2} \quad \text{and} \quad \frac{1}{1 + 2a_1 hB \cdot c_0^2} \qquad (28).$$

* *Journal de Liouville*, 1876 (quoted by Korteweg).

As a numerical example, let us take the case of water in a glass tube whose thickness is one-tenth of the radius. Assuming

$$\kappa = 2{\cdot}22 \times 10^{10},\quad E = 6{\cdot}03 \times 10^{11},\quad B = 6{\cdot}46 \times 10^{11}$$

in C.G.S. units*, we find that the velocity of longitudinal waves in the tube-wall must lie between

$$(E/\rho)^{\frac{1}{2}} \quad \text{and} \quad 1{\cdot}035(E/\rho)^{\frac{1}{2}},$$

and that the wave-velocity in the liquid will lie between

$$\cdot 744c_0 \quad \text{and} \quad \cdot 770c_0.$$

If we actually solve the quadratic (27) we find, with the same data, that the accurate value of the former velocity is

$$1{\cdot}015(E/\rho)^{\frac{1}{2}},$$

and that of the latter

$$\cdot 758c_0.$$

To avoid a possible misconception it may be well to point out explicitly that the forced vibrations of the tube-wall, due to waves of expansion in the contained liquid, are, under the present conditions, mainly longitudinal. This follows from the former of equations (6), which shews that the ratio w/u is of the order ma. An increase of pressure in any part of the tube tends (it is true) to produce in the first instance a radial enlargement, but this in turn tends to produce a longitudinal contraction; and, owing to the length of the waves, and to the relatively great velocity of wave-propagation in the solid, this latter effect is cumulative.

If we had assumed that the strains in the tube have at each instant the statical values corresponding to the

* The numbers refer to a specimen of flint glass whose elastic constants were determined by Everett (see his *Units and Physical Constants*).

actual distribution of pressure on the inner surface, we should have had, in place of (5),

$$\left.\begin{aligned} \frac{du}{dx} + \sigma\frac{w}{a} &= 0, \\ \sigma\frac{du}{dx} + \frac{w}{a} &= \frac{pa}{hB} \end{aligned}\right\} \quad . \quad . \quad . \quad (29),$$

and thence, on the supposition that u, w, p vary as e^{imx},

$$p = \frac{(1-\sigma^2)hB}{a^2}w = \frac{hE}{a^2}w \quad . \quad . \quad (30).$$

Combined with (18) and (24) this leads to

$$c^2 = \frac{c_o^2}{1 + 2\kappa a/hE} \quad . \quad . \quad . \quad (31).$$

This is the formula obtained by Korteweg, on the assumption just stated. It may easily be shown that the right hand side of (31) is an upper limit to the smaller root of (27). In the particular case previously considered, it gives

$$c = \cdot 759 c_o.$$

The assumption referred to may be justified (as a first approximation) by an appeal to a fundamental theorem in Vibrations.* In the cases at present in view, the motion of the tube-wall may be regarded as a forced vibration whose period is considerably longer than that of the free vibration of the same type (*i.e.*, of the same wave-length), so that the deformations have practically the "equilibrium values" corresponding to the instantaneous distribution of force.

It remains to notice the various modes of radial vibration of the system. These are found by putting $u = 0$, $dw/dx = 0$, in (5). If the time-factor be e^{int}, we find from (5) and (23),

$$n^2\left\{1 + \frac{a\rho_o}{h}\frac{I_o(\nu a)}{\nu a I_o'(\nu a)}\right\} = \frac{B}{\rho a^2} \quad . \quad . \quad (32),$$

where

$$\nu = in/c_o \quad . \quad . \quad . \quad . \quad (33).$$

* See Lord Rayleigh's *Sound*, § 100.

Hence we may put

$$n = zc_0/a \quad . \quad . \quad . \quad . \quad (34),$$

where z is a root of

$$z^2\left\{1 - \frac{a\rho_0}{h\rho}\frac{J_0(z)}{zJ_0'(z)}\right\} = \frac{B}{\rho c_0^2} \quad . \quad . \quad (35),$$

J_0 denoting the ordinary Bessel's Function of zero order. If the fraction $a\rho_0/h\rho$ were small, one root of this would be

$$z = (B/\rho c_0^2)^{\frac{1}{2}},$$

approximately ; this root determining the frequency of the radial vibrations of the wall as modified by the presence of the fluid. The remaining roots are in the neighbourhood of those of

$$J_0'(z) = 0,$$

and correspond to the various radial vibrations of a cylindrical mass of elastic fluid, as modified by the want of rigidity in the boundary. It is easy to continue the approximation, and so to estimate the extent of the modification in the several fundamental types of radial vibration, but it is hardly worth while to write down the results, as in cases of any interest the fraction $a\rho_0/h\rho$ would not be small. The only plan would then be to solve (35) by means of the tables of Bessel's Functions.

2. We have so far investigated only the case of fluid internal to the tube. When, as in Wertheim's experiments, the tube is immersed in liquid, we shall have in place of (6)

$$\left.\begin{aligned}\left(c^2 - \frac{B}{\rho}\right)u + \frac{i\sigma B}{ma\rho}w &= 0 \\ -\frac{i\sigma}{ma}\frac{B}{\rho}u + \left(c^2 - \frac{1}{m^2a^2}\frac{B}{\rho}\right)w &= -\frac{p - p'}{m^2h\rho}\end{aligned}\right\} \quad . \quad (36),$$

where p' denotes the external pressure. The solution of (17) appropriate to the external space is

$$p' = DK_0(\nu r) \quad . \quad . \quad . \quad (37),$$

where K_0 is defined by

$$K_0(z) = \int_0^\infty \cos(z \sinh u) du$$

$$= \left(\frac{\pi}{2z}\right)^{\frac{1}{2}} e^{-z}\left\{1 - \frac{1}{8z} + \frac{1 \cdot 3^2}{2!(8z)^2} - \cdots\right\} \quad . \quad (38),^*$$

the latter series being of the "semi-convergent" class, and therefore only available for large values of z. For small values of z we may use the form

$$K_0(z) = -(\gamma + \log \tfrac{1}{2}z) I_0(z) + \frac{z^2}{2^2} + \frac{z^4}{2^2 4^2}\left(1 + \frac{1}{2}\right) + \cdots \quad (39),$$

where $\gamma = \cdot 57721\ldots$. The condition analogous to (23), to be satisfied at the external surface, is

$$p' = m^2 c^2 \rho_0 a \frac{K_0(va)}{va K_0'(va)} \cdot w \quad . \quad . \quad (40),$$

The effect of this is that, in our previous work, we must replace

$$\frac{I_0(va)}{va I_0'(va)}$$

by

$$\frac{I_0(va)}{va I_0'(va)} - \frac{K_0(va)}{va K_0'(va)},$$

or, for sufficiently small values of va,

$$\frac{2}{v^2 a^2} - \log va,$$

where only the most important term in each fraction has been retained. When the wave-length is at all considerable as compared with the circumference of the tube, the second fraction is small compared with the first; *i.e.*, the effect of the external fluid may be neglected.

3. It has been assumed, so far, that the thickness of the tube is small compared with the radius. When this

* See Gray and Mathews, *Bessel Functions*, pp. 67, 68.

restriction is abandoned we must fall back on the general equations of Elasticity.*

In a usual notation, the equations of motions of an elastic solid free from extraneous force are

$$\rho\frac{d^2a}{dt^2} = (\lambda+\mu)\frac{d\delta}{dx} + \mu\nabla^2 a, \quad \&c., \quad \&c. \quad . \quad (41),$$

where

$$\delta = \frac{da}{dx} + \frac{d\beta}{dy} + \frac{d\gamma}{dz} \quad . \quad . \quad . \quad (42).$$

If the time factor be e^{imct}, it is known that the general solution of these is of the type

$$\alpha = -\frac{1}{h^2}\frac{d\delta}{dx} + u, \quad \beta = -\frac{1}{h^2}\frac{d\delta}{dy} + v, \quad \gamma = -\frac{1}{h^2}\frac{d\delta}{dz} + w \quad . \quad (43),$$

where δ is the solution of

$$(\nabla^2 + h^2)\delta = 0 \quad . \quad . \quad . \quad (44),$$

and u, v, w constitute the general solution of the system

$$\left.\begin{aligned} &(\nabla^2 + k^2)u = 0, \quad (\nabla^2 + k^2)v = 0, \quad (\nabla^2 + k^2)w = 0, \\ &\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0 \end{aligned}\right\} \quad . \quad (45.)\dagger$$

The constants h, k, which appear in these equations, are defined by the relations

$$h^2 = m^2c^2\rho/(\lambda+2\mu), \quad k^2 = m^2c^2\rho/\mu \quad . \quad . \quad (46).$$

In the case of symmetry about the axis of x, the equation (44) takes the form

$$\frac{d^2\delta}{dx^2} + \frac{d^2\delta}{dr^2} + \frac{1}{r}\frac{d\delta}{dr} + h^2\delta = 0 \quad . \quad . \quad . \quad (47),$$

where

$$r = (y^2+z^2)^{\frac{1}{2}}.$$

We may also write

$$u = \frac{d^2\chi}{dx^2} + k^2\chi, \quad v = \frac{d^2\chi}{dxdy}, \quad w = \frac{d^2\chi}{dxdz} \quad . \quad (48),$$

* It has not been found possible, in the investigation which follows, to preserve altogether the notation of the previous part of this paper.

† Cf. *Proc. Lond. Math. Soc.*, t. xiii., p. 192 (1882).

where χ is a function of x and r satisfying the equation $(\nabla^2+k^2)\chi=0$, or

$$\frac{d^2\chi}{dx^2}+\frac{d^2\chi}{dr^2}+\frac{1}{r}\frac{d\chi}{dr}+k^2\chi=0 \quad . \quad . \quad (49).$$

If we now assume that, as regards dependence on x, all our functions vary as e^{imx}, then, writing

$$r=(y\beta+z\gamma)/r,$$

so that r denotes the radial displacement, we have

$$a=-\frac{im}{k^2}\delta+(k^2-m^2)\chi, \quad r=-\frac{1}{k^2}\frac{d\delta}{dr}+im\frac{d\chi}{dr} \quad . \quad (50).$$

The normal stress across any plane perpendicular to r is then given by

$$\begin{aligned} p_{rr}&=\lambda\delta+2\mu\frac{dr}{dr} \\ &=\left(\lambda+2\mu-2\frac{\mu m^2}{k^2}\right)\delta+\frac{2\mu}{k^2r}\frac{d\delta}{dr} \\ &\qquad -2i\mu m(k^2-m^2)\chi-\frac{2i\mu m}{r}\frac{d\chi}{dr} \quad . \quad . \quad (51); \end{aligned}$$

and the shear parallel to x and r by

$$\frac{da}{dr}+\frac{dr}{dx}=-\frac{2im}{k^2}\frac{d\delta}{dr}+(k^2-2m^2)\frac{d\chi}{dr} \quad . \quad . \quad (52).$$

In the reduction of (51) use has been made of the differential equations (47) and (49).

The pressure in the fluid is subject to the same equation (17) as before, and we find, as the condition to be satisfied at the inner surface ($r=a$) of the cylindrical tube,

$$p_{rr}=-m^2c^2\rho_0 a\cdot\frac{I_0(\nu a)}{\nu a I_0'(\nu a)}\tau \quad . \quad . \quad . \quad (53),^*$$

There is a similar condition to be satisfied at the external surface, if the influence of the surrounding fluid is to be taken into account ; see § 2, above.

* The change of sign, from (23), is due to the fact that p denotes a *pressure*, and p_{rr} a *tension*.

For sufficiently long waves (53) reduces to

$$p_{rr} = -\frac{2m^2c^2\rho_0}{\nu^2 a}r \quad . \quad . \quad . \quad (54);$$

and the conditions to be satisfied for $r=a$ are therefore

$$\left(\lambda + 2\mu - \frac{2\mu m^2}{h^2}\right)\delta + \frac{2\mu}{h^2 r}\frac{d\zeta}{dr} - 2i\mu m(k^2 - m^2)\chi - \frac{2i\mu m}{r}\frac{d\chi}{dr}$$

$$= \frac{2m^2c^2\rho_0}{\nu^2 a}\left(\frac{1}{h^2}\frac{d\delta}{dr} - im\frac{d\chi}{dr}\right) \quad . \quad . \quad (55),$$

and

$$-\frac{2im}{h^2}\frac{d\zeta}{dr} + (k^2 - 2m^2)\frac{d\chi}{dr} = 0 \quad . \quad . \quad (56).$$

The conditions to be satisfied at the second surface may be obtained in a similar manner.

If we write

$$m^2 - h^2 = \eta^2, \quad m^2 - k^2 = \zeta^2 \quad . \quad . \quad . \quad (57),$$

the differential equations to be satisfied by the functions δ and χ take the forms

$$\frac{d^2\zeta}{dr^2} + \frac{1}{r}\frac{d\zeta}{dr} - \eta^2\zeta = 0 \quad . \quad . \quad . \quad (58),$$

$$\frac{d^2\chi}{dr^2} + \frac{1}{r}\frac{d\chi}{dr} - \zeta^2\chi = 0 \quad . \quad . \quad . \quad (59).$$

If we aim only at a determination of the wave-velocity in the fluid, as modified by the elasticity of the tube, c will be less than c_0, and *à fortiori* less than the velocity of free waves, whether of expansion or of distortion, in an infinite elastic solid. Hence the quantities ν, η, ζ will be real.

The case where the internal and external radii are both finite leads to some rather complicated equations. The problem is a little simplified if we suppose the external radius to be infinite, *i.e.*, we consider a tunnel bored in an infinite solid. This case is also of some interest as forming the other extreme to the state of things considered in § 1

above. The solutions of (58) and (59) which are finite for $r = \infty$ may be written

$$\delta = A\frac{K_0(\eta r)}{\eta K_0'(\eta a)}, \quad \chi = B\frac{K_0(\zeta r)}{\zeta K_0'(\zeta a)} \quad . \quad . \quad (60),$$

where A, B are arbitrary constants. Substituting in (55) and (56), and eliminating the ratio A/B, we find

$$(k^2 - 2m^2)\left\{\left(\lambda + 2\mu - \frac{2\mu m^2}{k^2}\right)\frac{K_0(\eta a)}{\eta a K_0'(\eta a)} + \frac{2\mu}{k^2 a^2} - \frac{2m^2 c^2 \rho_0}{\nu^2 k^2 a^2}\right\}$$

$$= -\frac{4m^2}{k^2}\left\{\mu(k^2 - m^2)\frac{K_0(\zeta a)}{\zeta a K_0'(\zeta a)} + \frac{\mu}{a^2} - \frac{m^2 c^2 \rho_0}{\nu^2 a^2}\right\} . \quad (61).$$

This equation, in conjunction with (18) and (57), determines the wave-velocity c.

In the present investigation, ηa and ζa are real, and less than ma, which is by hypothesis small. Now we have seen from (39) that for small values of z the fraction

$$\frac{K_0(z)}{zK_0'(z)}$$

is of the order $\log z$. The terms in (61) which have a coefficient of this form are therefore of the order $z^2 \log z$ as compared with the remainder, and may (for sufficiently long waves) be neglected. The equation then takes the simple form

$$\mu\nu^2/m^2 = \rho_0 c^2 = \kappa c^2/c_0^2 \quad . \quad . \quad . \quad (62),$$

where κ denotes the cubical elasticity of the fluid. If we substitute the value of ν^2 from (18), this gives

$$\frac{c^2}{c_0^2} = \frac{\mu}{\kappa + \mu} \quad . \quad . \quad . \quad . \quad (63).$$

The value of μ for glass is (roughly speaking) about 10 times the value of κ for water. This would give a diminution of about 5 per cent. in the velocity of sound in the water.

The formula (63) is precisely what we should obtain

on the hypothesis that the strains in the solid have at each instant the equilibrium values corresponding to the internal pressure. In the case of a cylindrical cavity bored in an infinite solid, the statical value of the displacement at the surface ($r=a$) due to an internal pressure p is

$$w = pa/2\mu \quad . \quad . \quad . \quad . \quad (64).^*$$

Comparing this with (24) we obtain the results (62) and (63).

The corresponding approximation for a tube whose internal and external radii (a and b) are comparable with one another is easily investigated. If the tube be subject to a statical pressure on the interior, the radial displacement (w) at the inner surface is found, on the hypothesis that the tube is free to contract longitudinally, to be

$$w = \frac{(\lambda+2\mu)a^2+(3\lambda+2\mu)b^2}{2\mu(3\lambda+2\mu)(b^2-a^2)}pa \quad . \quad . \quad (65).$$

Compared with (24), this gives

$$\frac{c^2}{c_0^2} = 1 \div \left\{1 + \frac{\kappa}{\mu}\cdot\frac{(\lambda+2\mu)a^2+(3\lambda+2\mu)b^2}{(3\lambda+2\mu)(b^2-a^2)}\right\} \quad . \quad (66).$$

In the case of $b=a+h$, where h/a is small, this becomes

$$\frac{c^2}{c_0^2} = 1 \div \left(1 + \frac{2a\kappa}{hE}\right) \quad . \quad . \quad . \quad (67),$$

in agreement with (31).

* See Love's *Elasticity*, t. i., p. 226.

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X. The New Gold Discoveries.

By EDUARD SUESS (Vienna),

Honorary Member of the Manchester Literary and Philosophical Society.

Received and read April 5th, 1898.

Reference has lately been made in the Proceedings of the Society to my small book on "The Future of Gold," published in 1877, and a desire has been expressed to learn my opinion on the present situation. My opinion is, that the succession of rich discoveries and the energy of mining operations accelerate the exhaustion of the resources in gold offered by nature to mankind, and at the same time hasten the approach of a universal economic danger.

When Germany, after the war of 1870, adopted the gold standard, the Government was supported by distinguished men, of well-deserved renown in economical affairs, but without the necessary deference to the geological side of the question. That is why, in 1877, I ventured to remind them that the production of silver would not be reduced in the ratio of the fall in its value, that the source of available gold would not be sufficient to provide a gold standard for the whole world, and that the epoch was inevitable, probably after a few centuries, when the production of gold must diminish steadily and in a high degree, and this metal, with increasing rarity, would no longer be able to retain its present economic position.

The evidence seems very clear. The Greek philosophers knew that gold was only found on the utmost

July 13th, 1898.

frontiers of civilisation, and Humboldt emphasized the fact that all subsequent centuries have proved the truth of this observation. The same experience has occurred, since Humboldt's time, in Eastern Siberia, in the Rand, in Western Australia and on the Yukon, up to the present day. The rich discoveries have always been dependent on geographical expansion. Each such discovery has yielded gold to mankind through a certain time, according to the richness of the deposit and the energy of working, and has then ceased. Now, as the extent of unexplored country is limited, and the distribution of gold-bearing rocks within these districts is also limited, it must never be forgotten that the entire sum of gold still attainable by man is also a limited figure.

This constant displacement of mining operations forces them beyond the regions of congenial climate. The consequences are well shown in Mr. Goodrich's description of gold-mining on the Yukon, contained in Spurr's excellent Alaskan Report to the U. S. Geological Survey. Firstly, we must remember that all gold from the Yukon comes from placers, and consequently cannot be compared to the gold won at the Treadwell Mine, Alaska, which is mined under wholly different and exceptionally happy circumstances on Douglas Island, near the entrance to Lynn channel. The Cassiar district, near Dease Lake, British Columbia, is of the same type as the Yukon placers. This district gave 1,000,000 dollars in 1874, then receded gradually to 22,000 dollars in 1895, and is now exhausted. Cassiar has given experienced prospectors and miners to the Yukon district. But here, on the banks of the Yukon, frost reigns through eight months of the year.

The prolonged and intense cold is a serious impediment to placer work and only the richest deposits can pay. Gold of coarse grain is, by the high specific gravity of the

metal, much easier to separate from the wash dirt, than the fine gold particles of even a rich silt. Therefore, the prospectors push up to the higher parts of the creeks, where frost and snow are even more excessive, food is wanting, and every sort of transport becomes extremely difficult. In some places, the miners melt the frozen ground by fire, sink shafts and throw out the pay-dirt for washing during the short summer. But, as the number of persons who endure all these hardships is small, only the richest places are worked, and every new and better find causes the desertion of the old place.

In 1886 Stewart River was abandoned when Forty Mile Creek was discovered, and in 1896 Forty Mile Creek was quitted for Klondike. The consequence is a very incomplete harvest. It is improbable that hydraulic arrangements in this severe climate will pay, and the establishment of quartz mining is likewise held improbable by authorities.

The production from the placers of all the Alaskan river valleys in 1896, together with the Yukon creeks on British territory, but without those on Cook's Inlet on the seaboard, was estimated by the Alaskan Mining Record at 2,170,000 dollars, and by Mr. Goodrich at 1,700,000 dollars, showing how difficult it is to obtain trustworthy figures from districts of this kind.

In comparing the various fluctuations which the world's production of gold shows since the early ages, I, in 1877, thought myself entitled to suppose that these fluctuations would continue during the next few centuries until the time of final exhaustion. This supposition was erroneous. The facilitation of every sort of communication which has taken place during these 21 years, the immense expansion of the white race, the magazine rifle, the increased experience of the prospector, the fabulous credulity of the mass risking thousands after thousands in £1 shares

on enterprises with but the faintest spark of hope, and many other circumstances, combine to the effect that, *in place of the continued fluctuations*, presumed by me in 1877, *the whole production of the world now tends to unite into one great wave*, and, consequently, to hasten the end and to increase the danger. It is a further consequence of this state of things, that the distance of this end may no longer be measurable by centuries.

But, along with this increase of the world's production, every sort of activity has increased all over the world, hundreds of new exigencies have arisen, and the question may be raised, whether the production of gold and the new necessities have grown in a comparable manner during recent years.

Every figure in these matters can only be more or less rudely approximate. The figures of production, of export and import of gold, which I beg leave to cite below, are taken from the last excellent publication of the U.S. Director of the Mint, Mr. Preston. I am aware, that in these figures the production of gold for the United States is given for the calendar year, as for the rest of the world, and the figures of export and import are given for the U.S. fiscal year ending June 30th. This may displace a part of the figures, but cannot affect the general conclusion.

In 1887 the world's production had decreased to 21·8 millions sterling, and from that time the rise was constant, until in 1897 50 millions sterling was reached; the estimate for 1898 is 55 or 56 millions sterling.

Three-quarters of this sum is produced by four parts of the world: Australia, South Africa, Russia, and the United States. It is a very wide-spread delusion that these four countries really deliver up all their gold to the world's use. In reality, the case is very different.

Let us only consider the last four years, 1893-96, for which we possess the necessary figures.

The net export of gold from *Australia* during these four years teaches that one-half of the production (82 million dollars out of 167 million dollars) was retained for home purposes, and only one-half was exported.

South Africa, in the same time, retained about 31 per cent. of her production, and delivered up 69 per cent. (108 million dollars out of 158·2 million dollars).

Russia, during all these years, shows high figures of net import. We see that Russia retained all her own production, and continued to draw gold from other parts of the world.

The *United States* have, under the influence of economic changes, exported in some years a greater and in others a smaller part of their production; it has even happened that they have exported more gold than was produced. But since the middle of 1896 the current has wholly changed. Since that time they also have retained all their production, and drawn on the rest of the world.

If you will take the trouble to subtract the production of these four countries from the production of the world, and add their net export to the rest (always basing on Mr. Preston's figures), you may obtain the approximate sum of new gold really left to the disposal of the rest of the world during this time.

These figures are :—

1893, world's production 33·0 millions sterling reduced to 16·8 millions sterling.

1894, world's production 38·0 millions sterling reduced to 14·1 millions sterling.

1895, world's production 41·8 millions sterling reduced to 28·7 millions sterling.

1896, world's production 42·6 millions sterling reduced to *minus* 1·7 millions sterling.

This means a world's production of 38·7 millions sterling per annum, out of which only 14·5 millions sterling per

annum were at the disposal of the world excepting the four countries named. At the same time the variability of the reduced figures may be seen (one of them showing even a negative result), and the treacherous character of averages. But, although the production varies, the variability of demand is incomparably greater, having regard to quantity as well as to origin. It may be said, that the bad harvest in Europe, and Russia's preparations for a gold currency, are claims of a temporary and passing character which give abnormal figures. But the demands are very often of a temporary character, and it is a justifiable requirement that the disposable quantity of gold should be adequate even to meet much stronger claims; let us not speak of war.

In 1897 the position was no better, and it is hard to assume that it will be much improved in 1898.

In *Australia* the export of agricultural produce is rather retrograde, English capital has also been withdrawn, and therefore Australia gives more gold; the export of gold to Europe has been strong in 1897 and is expected to be considerable in 1898 (say 11 to 13 millions sterling).

South Africa delivers up a great part of her increasing production, but part of the outcrop mines on the Rand have already closed up; the life of others is reckoned approximately to last four or five years longer. The life of the deep levels is estimated by mining authorities at about 25 years. Let us accept these figures. South Africa is now not only one of the very first producers, but also delivers up the greatest part of her gold, and let us ask, What after 25 years?

Russia has continued her gold policy, she has retained her own produce (6·5 millions sterling or more) and has continued to import foreign gold. Mr. Witte's last report says, that in 1897, 10·9 million dollars have been added to the Government's gold treasure, besides very large sums of gold which entered into commerce.

The *United States* in 1897 likewise retained their own production (11 millions sterling), and continued to draw on the rest of the world. Their net export in trade in 1897 amounted to about 70 millions sterling. During recent years a certain amount of American railway securities seems to have returned homewards, thus narrowing one of the channels by which Europe received American gold.

Besides these variable contingencies, and besides the hoarding of gold treasure by Austria-Hungary and Japan, there appear a great number of exigencies which are not temporary but are constantly increasing. I first mention the consumption of gold in the arts and industries, which for the world (excepting the said four countries), is estimated at about 9 millions sterling per annum. Then comes the increasing demand for circulation in the very few parts of Europe which possess a gold currency. Everybody feels the necessity of reinforced metallic reserves for banking institutions to face the quite incalculable quantity of paper values and the manifold kinds of liabilities. Let me call to your mind that the increase of business of the Deutsche Reichsbank in 1897 alone amounted to 500 millions sterling, that the demands for new capital at London were 49·1 millions sterling in 1893 and rose to 91·8, 104·7, 152·8 in the three succeeding years respectively, and in 1897 to 157·2. I do not add more figures, as we all live in the midst of the bee-hive ourselves.

The effect of all this is *that, although the world's production of gold is more than twice as great as it was ten years ago, still the struggle for gold is, to say the least, quite as sharp as it was then.*

But all this is only one side of this disastrous affair. Now come the consequences of the yearly increasing difference in the relative values of gold and silver. I do

not intend to speak of the influence of this fact on prices, nor on different branches of industrial and agricultural activity, but I wish to say a few words on Asia.

India has from 1893 to 1896 produced 18·55 millions sterling of gold. Exports and imports of gold have been extremely variable; still India had a net import of 2·29 millions sterling for these years, so that the Indian production also was not delivered up to Europe. But this home production is of small account for the country. India, deeply and innocently injured by the fall of silver, now hardly strong enough to bear the burden of her debts amounting already to about 18 millions sterling in gold per annum, loaded with new gold debts to pay old interest and with new experiments; the same India to which in 1892 an eminent Indian statesman thought to assure a gold circulation by means of merely 15 millions sterling, and which is now, six years later and after the great increase of the world's production, haunted by the spectre of a gold standard without gold; this vast and rich empire, blessed by nature and sprinkled with the blood of so many of England's noblest children, is at this moment a deterring way-mark on the path which China is being forced to enter. Can any earnest man, casting his eye over the world's increasing traffic, and over this great and increasing gold monetary movement, which we are witnessing, I say, can anyone believe that this process may be called upon by a modern Joshua to stand still at 1s. 4d.? But is not this forced application of a foreign standard the resurrection of that colonial policy of past times, condemned by history and by civilisation? Does advanced Europe, proud of her Christianity, indeed think of subduing foreign nations by giving to each of their liabilities an ulcerating character? Do enlightened statesmen not perceive, *that in Asia*, that ocean of mankind, *no reasonable policy of whatever direction is compatible with a gold standard?*

These are the conditions under which we float towards a great monetary crisis. Yukon will not be the last of the rich discoveries. Some others probably are still reserved for the near future, be it on the north of the Kuenlun Range, or in Central Africa, in Siberia, or in any other distant part of the world. Other sources will decline, but, *in toto*, the world's production will for some time continue to increase. The necessities of mankind will also continue to increase, and probably even in a higher degree. Then the apex of the wave of production will be attained, the final decrease of gold will begin, but the necessities of mankind will continue to increase. Perhaps America will in the meantime decide upon the free coinage of silver, and, setting up a monetary barrier right across the traffic of the world, will defer the final crisis of gold. We cannot foresee the single events, but we can see the line of drift.

Germany has loosened the old tie of gold and silver, without anticipating the consequences. In the long run the profits have, without any merit, fallen to the bond-holders, and the losses, without any fault, to the debtors. The holders of foreign securities in England are actually in the first line responsible to the world for the continuation of this state of monetary affairs, so perilous also for themselves.

I know well, that personal interest is a very strong item, but national interest is a stronger item, and when national interest speaks, personal interest must rest silent. But the interest of humanity is a stronger item still, and even if national interest should eventually point another way, which I contend is not here the case for England, the common interest of humanity must prevail. A great nation, claiming to be a leading member of mankind, must feel this as a duty.

Manchester Memoirs, Vol. xlii. (1898), *No.* **11.**

XI. Hymenoptera Orientalia, or Contributions to a knowledge of the Hymenoptera of the Oriental Zoological Region. Part VII.

By PETER CAMERON.

[*Communicated by J. Cosmo Melvill, M.A., F.L.S.*]

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Since the publication of Part VI. of this series of papers on the *Hymenoptera* of the Oriental Zoological Region, there has appeared Col. C. T. Bingham's "Fauna of British India, *Hymenoptera*," Vol. I., which deals with the Aculeate Section of the Order, except the Ants. To facilitate reference I have, in this paper, followed Col. Bingham's arrangement, giving indications of the positions my new species will occupy in the system adopted by him. Further, I have pointed out certain omissions and corrections in his work.

It is necessary to say here that Col. Bingham's book only refers to British India, Burma and Ceylon, whereas the scope of my papers includes the Oriental Zoological Region as defined by Mr. A. R. Wallace—a very much wider area.

MUTILLIDÆ.

MUTILLA VISRARA, *sp. nov.*

Long. 8 mm.

Hab. Trincomali, Ceylon (*Yerbury*).

Allied to *M. niveosignata*, but differs in the basal segment not being "almost bare" at the base, but covered

with long black hair, although not so thickly as at the apex, where it is densely covered with long fulvous hair, in the second segment beneath not having three longitudinal keels, in the ventral segments and legs being distinctly piceous, and in being two mm. smaller.

Head slightly wider, but not quite so long as the thorax; rounded in front, but not quite so much so behind, very coarsely rugosely punctured, the punctures longest and deepest in the centre of the front and vertex; behind the eyes it is developed to a greater extent than their greatest length; the eyes are small. Front and vertex covered with long black hairs; above the antennæ more thickly with silvery hair; on the clypeus it is equally long and pale golden. Antennal tubercles piceous at the apex, shining. Clypeus reddish, the apex bordered with black. Mandibles broadly red in the middle. Antennæ longer than the head and thorax united; distinctly tapering towards the apex; the scape shining, thickly covered with long silvery hair; piceous at the apex; the flagellum bare of hair except at the base, distinctly pruinose towards the apex; black, the apical joints rufous beneath; the third joint about one-third longer than the fourth; thorax quadrangular, scarcely widened towards the apex; the mesonotum, with a semicircular space on the top of the median segment, reddish, coarsely punctured, the punctures large and deep; the pronotum bearing long, blackish hairs; the mesonotum with depressed, pale golden, shorter hairs; the top of the median segment rounded, and bearing a row of large, deep punctures; the rest of it oblique; the sides with a row of large areæ; the centre has a blistered appearance and an indistinct keel down its centre; it is sparsely covered with long blackish hairs. Propleuræ reticulated; the metapleuræ also reticulated, but with the reticulations much larger and deeper; the mesopleuræ smooth, the lower part densely covered with long silvery

hair; over the middle coxæ it is rufous. Legs black; the anterior coxæ and femora rufous; the other femora, tibiæ and tarsi more or less piceous; the femora more sparsely, the tibiæ and tarsi much more thickly covered with long silvery hair; the tibial spines thick, testaceous; the calcaria white. Abdomen as long as the head and thorax united; the basal segment irregularly reticulated; the base covered, but not thickly, with long, black hair; the apex fringed with long, fulvous, golden hair, which extends on to the base of the second segment; the second segment coarsely irregularly reticulated, most strongly at the sides, thickly covered with long, black hair; in its centre, in front of the middle, are two oval marks of silvery pubescence; the other segments are covered with long, black pubescence; on the third, are two marks of silvery pubescence, but wider and shorter than those on the second; the apical segments are slightly fringed with silvery hairs at their apices; the pygidial area smooth, shining, impunctate; covered thickly at the sides with long, black and a few silvery hairs. The first and second ventral segments piceous; the basal obliquely triangularly raised in the middle; the basal part depressed before the apex; the second segment broadly depressed in the middle at the base; its apical half bearing large, deep, irregular punctures; sparsely covered with long, white hairs; the other segments closely punctured at the apices, thickly covered with long, silvery hair. The apices of the third and fourth ventral segments are obscure testaceous in the middle.

MUTILLA ELTOLA, *sp. nov.*

Long. fere 7 mm.

Hab. Trincomali, Ceylon (*Yerbury*).

A species very similar in form and markings to *M. rothneyi* Cam., but may be known from it by the median segment not having "a single central spine posteriorly."

Head large, subquadrate, very slightly narrowed gradually behind the eyes; black; the vertex broadly in the middle, and the front broadly, in the centre to the middle of the eyes, red, sparsely covered with long, fuscous, intermixed with shorter silvery, hair; the front and vertex strongly and distinctly longitudinally striolated, the striæ running into coarse punctures over the antennæ; the striæ behind the eyes stout, sharp, slightly oblique, and not extending below the level of the eyes; the antennal tubercles very smooth, rufo-piceous. Oral region piceous-red; the clypeus in the middle incised, the sides of the incision forming two stout projecting teeth. Mandibles ferruginous; the teeth black; except at the apex, sparsely covered with long, pale golden hair; thorax at the base very slightly narrower and not very much longer than the head, of nearly equal width throughout; the mesonotum, except at the base and at the sides, rufous, the black on the base being broader than on the sides, very coarsely longitudinally reticulated, the reticulations becoming wider and larger towards the apex; the median segment with an oblique slope; reticulated, the reticulations much larger than on the mesonotum. The sides of the mesonotum above with projecting teeth; those at the base indistinct; the central very large, straight, sharp at the apex; that behind it blunt, curved, longer; the teeth on the median segment finer, curved, five in number; the central being the longest. Pleuræ not excavated, smooth, shining, impunctate; the propleuræ at the apex piceous; the base of the meso- and the meta-pleuræ thickly covered with longish, silvery pubescence. Antennæ longish, distinctly tapering towards the apex; the under side of the scape of the second, and of the base of the third joint, rufous; the scape punctured, thickly covered with longish silvery hairs; the flagellum thickly covered with a silvery down; the third joint twice the length of the fourth.

Legs black, thickly covered with longish, silvery hair; the tarsi towards the apex more or less rufous; the calcaria white. Abdomen as long as the head and thorax united, black; a silvery spot on the apex of the basal segment at the apex; a large, round, central and a smaller, more elongate mark on the side of the second segment, and the centre of the fourth and fifth segments broadly in the centre, covered with silvery pubescence; the basal segments punctured, sparsely covered with long black hairs; the pygidium shining, covered with long, black hairs; the centre slightly raised, impunctate; the rest punctured, the punctures large, moderately deep and clearly separated. The basal ventral segment testaceous; the apical three-fourths keeled down the middle; the keel black, dilated at the base, but not much; the second segment with large, shallow punctures, sparsely covered with long, pale hairs; towards the apex the middle projects into a stout, somewhat triangular, tooth; the other segments closely and rather strongly punctured except at the base, and covered with long hair; the hypopygium closely punctured and for the greater part testaceous.

Might be the ♀ of *M. œdipus*, but this is a point which can only be settled by direct observation.

MUTILLA SIMPLICATA, *sp. nov.*

Long 10 mm ♀.

Hab. Mahaganay, Ceylon (*Verbury*).

Belongs to the limited group of *Mutilla kanara* Cam. and *M. atomus* André, distinguished by having no spots on the abdomen, having instead broad bands of reddish-fulvous pubescence; the legs red, the antennæ black, reddish at the base. *M. kanara* is a larger species than this, its thorax is red; the head covered above with fulvous pubescence; and the second abdominal segment fulvous

at the apex only; *M. atomus* has also the head red, and the antennæ and thorax entirely ferruginous.

Antennæ stout, the basal three joints ferruginous; the scape sparsely covered with longish, pale golden hair; the flagellum with a white, microscopic pile. Head as wide as the thorax; dark ferruginous, darker on the vertex; coarsely punctured, sparsely covered with long, pale golden hair; the third joint of the antennæ as long as the following two united. Thorax rounded in front, not much narrowed behind, the sides straight; above coarsely rugosely reticulated, sparsely covered with long, black hairs. Legs entirely ferruginous-red, covered with long, white hair; the spurs pale; the tibial spines stout, reddish. Abdomen black, velvety; the apex of the basal segment covered rather densely with long, pale golden hair, the second segment broadly at the base, and the third and fourth entirely with golden, depressed pubescence; the other segments black, and bearing black hairs; the pygidial area strongly longitudinally striolated.

The thorax in my only example is somewhat crushed, and I cannot satisfactorily describe its sides; the mesopleuræ appear, however, to be smooth; the median segment coarsely punctured, and sparsely covered with long, white hair.

MUTILLA ŒDIPUS Cam.

Col. Bingham (*l.c.*, p. 27) gives *Mutilla œdipus* Cam. (he calls it *contracta*) as the ♂ of *M. rothneyi* Cam. There is, however, no evidence, except surmise, that this is the case; and, like so many other species, it had better be kept distinct until direct observation shows what its female really is. Col. Bingham states further that it is not really apterous—that its wings have been torn off. There is nothing novel in the fact of there being an apterous male *Mutilla*, for there is more

than one undoubted instance known; and, when such is the case, the form of the thorax in the ♂ approximates to that of the females. Such is certainly the case with *M. œdipus*, in which I am not only unable to find any trace of there having been wings, but so far as the hind wings are concerned, I cannot see where they could have been attached. The contracted thorax is well shown in my figure (*Manch. Memoirs*, vol. xli., No. 4, pl. 4, f. 13). A comparison of my figure with that of *M. perfecta* Rad., shows great similarity between these apterous males in structure of the thorax.*

Mutilla acidalia Cam., described (*Manch. Memoirs*, *l.c.*, p. 56) in both sexes by me, is omitted entirely by Bingham.

Col. Bingham also has overlooked my description of both sexes of *Mutilla opulenta* (*Manch. Memoirs*, *l.c.*, p. 57).

Mutilla apicipennis *Cam.*

This species is not mentioned by Bingham under this name, unless he regards it as identical with *M. pedunculata* Klug (*l.c.*, p. 51). If so, his description of the latter is defective in a very important point, namely, he says nothing about the petiole being serrate, or irregularly armed with teeth beneath, this being one of the most specific features whereby *M. pedunculata* is distinguished from the very closely-allied *M. chlorotica* Grib. I have not at hand Klug's original description, but *M. apicipennis* does not agree with Gribodo's description of *M. pedunculata*, *e.g.*, the second abdominal segment is not coarsely and strongly rugosely punctured, *M. apicipennis* having it only irregularly roughened at the base; in *M.*

* For details regarding the apterous males, as well as the generic position of *Mutilla apicipennis* and its allies, see the work of Radoszkowski, *Hora Soc. Ent. Ross.*, XIX. 1885, and the more recent paper by M. Ernest André, *Mém. Soc. Zool. France*, 1896, pp. 261-277.

pedunculata the epipygium is said to be smooth, longitudinally carinate in the middle; in *M. apicipennis* it is only smooth at the base, the rest closely rugosely punctured and without a trace of a keel (*cf.*, Gribodo, *Ann. Mus. Civ. Genova*, xx., p. 390). *M. pedunculata* is known from Arabia and Berbera. It, with *M. chlorotica* Grib., and perhaps *M. asiatica* Rad., forms the genus or subgenus *Tricholabiodes* Rad.

When I described *M. apicipennis*, I relied (not having Klug's work to consult) on the description of *M. pedunculata* given by Sichel and Radoszkowski in their Monograph of the Old World *Mutillidæ*. Their *M. pedunculata* is assuredly not *M. apicipennis*, but is perhaps *M. chlorotica* Grib. It has not the petiole serrate beneath, nor is any mention made of there being two furrows on the mesonotum. *M. chlorotica* (also from Arabia) differs from *M. apicipennis* in having the abdomen without any black, the petiole without teeth, and all the abdominal segments obliquely punctured. It seems to me therefore clear that *M. pedunculata* Klug must be deleted from the lists of Oriental *Mutillidæ*, unless the example from "Western India" recorded by Bingham, be the true *M. pedunculata*, in which case his description does not fit it.

MUTILLA POSTHUMA, *sp. nov.*

Long. 4·5 mm.

Hab. Trincomali, Ceylon (*Verbury*).

In the table (*Manchester Memoirs*, Vol. 5 (1892), p. 123-4) this species comes in at "15. Head red, wholly or in part."

16. Abdomen with one spot and one band.

16*a*. Head and thorax with golden hair; antennæ entirely rufo-testaceous; pygidial area black, not longitudinally striated. Length 7 mm. *M. poonaensis* Cam.

16*b*. Head and thorax without golden hair; antennæ at the base pallid testaceous, fuscous towards the apex; the pygidial area testaceous, distinctly longitudinally striated. Length 4·5 mm. *M. posthuma.*

The little *M. atomus* André is readily separated from it by the pygidium not being striated. Antennæ stout, thickened towards the apex; pallid-testaceous, infuscated towards the apex, sparsely pilose, the third and fourth joints equal in length. Head, if anything, wider than the thorax; the front and vertex strongly punctured, dark rufo-testaceous; the oral region and the tubercles pallid-testaceous, as is also the base of the mandibles; the tubercles large, shining; behind, the head is developed one-half the length of the eyes. Thorax, with the sides above, straight, slightly and gradually narrowed towards the apex; the mesonotum coarsely punctured; the median segment with a slight oblique slope, rounded at the top. Pleuræ slightly excavated, smooth and shining; the middle with long, white hair. Legs thickly covered with long, white hair; testaceous, the femora darker, the tarsi paler. Abdomen a little longer than the head and thorax; black, with a slight violaceous tinge; the base and apical segments rather thickly covered with long, pale hair; the anal segment rufo-testaceous, strongly longitudinally striolated. Ventral surface black; the basal segment testaceous, with a straight, blunt centre; the other segments fringed thickly with long, white hair.

MUTILLA CONSOCIATA, *sp. nov.*

Long. 5 mm. ♀.

Hab. Trincomali, Ceylon (*Yerbury*).

Agrees closely with *M. posthuma*; but instead of the apex of the second abdominal segment being entirely covered with silvery pubescence, it has only a square mark of it in the centre, there being also similar marks on the fourth and fifth; the anal segment is black and is only finely, not strongly, punctured, and, at the sides, is thickly covered with longish, stiff, black hairs; the apex of the median segment is more sharply oblique, and not rounded

at the top; the vertex is not so dark, nor the base of the antennæ so light, in tint. It also resembles *M. regia* Sm., but that is much larger; its abdomen has a very decided bluish tint; its mesonotum has in front a large mark of silvery pubescence, and the median segment has a rounded slope. *M. poonaensis* may easily be known by its thorax being longer and distinctly narrowed towards the apex, the thorax of *M. consociata* being of uniform width.

Head as wide as the thorax; the front and vertex coarsely punctured, the vertex slightly infuscated; and with only a few short, black hairs; the oral region with some long silvery hairs; the tips of the mandibles black. Antennæ stout, rufous, blackish towards the apex; the scape with a few large punctures and a few silvery hairs; the third joint twice the length of the second and one-half the length of the fourth. Thorax short, of uniform width; the mesonotum strongly punctured, sparsely covered with long, silvery hair; the median segments with a sharply oblique slope; reticulated, and bearing long, fuscous hair; the reticulations are weaker and smaller on the bottom. Pleuræ shining, not excavated; the middle thickly covered with long, depressed, silvery hair. Legs rufo-testaceous, thickly covered with long, white hair; the hinder knees infuscated. Abdomen hardly so long as the head and thorax united; deep black; an elongated mark of silvery pubescence in the centre of the second segment, a transverse one at its apex, and one in the centre of the fourth and fifth segments; the anal segment finely longitudinally striated; the centre in the middle piceous; the ventral segments thickly covered with long, white, silvery hair.

MUTILLA INDECORA, *sp. nov.* (Pl. 4, fig. 1.)

Long. 4 mm.

Hab. Ceylon, Trincomali (*Yerbury*).

Agrees with *M. serratula* Cam. and *M. veda* Cam. in having the thorax spined and the abdomen with golden markings. From *M. serratula* it may be known by its head being red, not black, by having only a golden mark on the apex of the second abdominal segment, not a complete band, and by the metapleuræ being coarsely punctured; *M. veda* is to be known from it by the large belt of golden pubescence on the apex of the second abdominal segment, by the much less strongly punctured metapleuræ, and by the apical abdominal segment above being densely covered with golden pubescence.

Head, if anything, wider than the thorax; dark rufous, slightly infuscated on the vertex; strongly and coarsely punctured, thickly covered with long fuscous hair; the space behind the eyes as long as the eyes; the oral region thickly covered with long, white hair. Mandibles rufous, their apices broadly black. Antennæ stout, the flagellum blackish; the scape rufo-testaceous, shining, sparsely covered with longish, white hair, and having some large punctures. Thorax somewhat narrower than the head and about double its length, of nearly equal length throughout, closely rugosely punctured; the median segment with an oblique slope, and punctured all over, the punctures distinctly separated; at the top is one large central tooth and four smaller lateral ones. Pro-, meso- and base of meta-pleuræ shining, impunctate; the rest of the metapleuræ strongly punctured, the punctures large and deep. At the apex of the mesopleuræ above is a large tooth; on the sloping part of the metapleuræ are six smaller teeth also above. Legs stout, rufo-testaceous, the spurs paler; thickly covered with long, pale, fuscous hair; on the hinder tibiæ are four long, sharp spines. Abdomen broad at the base; closely punctured; on the apex of the first segment is a roundish spot of golden pubescence; on the apex of the second in the middle is a similar mark,

double its size, and narrowed at the base; on the centre of the third is a small patch; and the apical segment is entirely covered with a long, pale golden hair. Ventral segments punctured, closely covered with long, white hair.

MUTILLA ERNESTI, *sp. nov.*

Long. 5 mm.

Hab. Trincomali, Ceylon (*Yerbury*).

Belongs to the group of *M. serratula* Cam., except that the head is not black, only dark ferruginous. From *M. veda* and *M. indecora*, it may be known by the darker colour of the head and thorax, by the deeper tint of the abdominal marks, and by the second abdominal segment being distinctly longitudinally striolated.

Head as wide as the thorax; the sides behind the eyes straight, and as long as the eyes; strongly punctured, shining, sparsely covered with long, fuscous hair; the antennal tubercles shining, smooth, piceous at the apex. Oral region piceous; mandibles ferruginous, broadly black at the apex. The scape and basal two joints of the flagellum ferruginous; the flagellum brownish beneath; the third joint is distinctly longer than the fourth. Thorax about twice the length of the head and of about the same width, scarcely narrowed towards the apex; above coarsely rugosely punctured; at the base the sides project into a stout, blunt, triangular tooth, in the middle there is a smaller triangular tooth, and at the top of the median segment on the sides are a few teeth, the lower indistinct. The median segment has a sharp oblique slope, which is for the greater part blackish; the top serrate, the three middle teeth being much the larger. Except the apex of the metapleuræ, which is strongly punctured, the pleuræ are shining and impunctate. Abdomen black; the apex of the first segment with a small, the second with

a much larger, semicircular mark of deep orange pubescence, mixed with pale golden hairs; the second segment longitudinally striolated.

MUTILLA LITIGIOSA, *sp. nov.*

Long. 8 mm. ♀.

Hab. Trincomali, Ceylon.

In Bingham's table, this species comes in on p. 4—"Second abdominal segment with two spots, the spots medial, one above the other."

The spots golden.

Legs and scape of antennæ red.	*M. pulla* André.
„ „ „ black.	*M. litigiosa.*

Antennæ stout, tapering very distinctly towards the apex, the scape sparsely covered with longish white hair; the flagellum bare, or with a microscopic pile; the apex of the scape and the base of the flagellum rufous beneath; the third joint nearly one-half longer than the fourth. Head as wide as the middle of the thorax; coarsely rugosely punctured; sparsely covered with long, fuscous hair on the vertex; on the face and oral region the hairs are paler, silvery white and more numerous; the base of the mandibles piceous. Thorax rufous, except on the sternum; rounded at the base and apex, becoming gradually, but not very much, thicker towards the apex; above coarsely rugosely punctured; the pleuræ excavated, smooth and shining; their lower part black, and thickly covered with long, white hair; the median segment broadly rounded at the top, and with an oblique slope. Legs black; the tarsi more or less rufous towards the apex; the femora sparsely, the tibiæ more thickly, covered with white hairs, the tarsi with the hairs thicker and stiffer; the calcaria pale. Abdomen longer than the head and thorax united; black; a fringe of longish,

golden hair on the apex of the first segment; a roundish mark near the base of the second segment in the middle; a semicircular one on the extreme apex; and a broad belt of golden pubescence on the apex of the third; the other segments at the sides with long, pale golden hair; the pygidial area rufous in the centre, strongly and uniformly longitudinally striolated. The basal ventral segment rufous at the sides; the base with two stout curved keels; shining; the central keel stout, straight; the second segment stoutly punctured; the other segments at the base finely transversely striated; their apices closely punctured, as are also their sides; and they are covered sparsely with long, pale hair.

This species has a considerable resemblance to *M. buddha* Cam., but that is longer; its legs are stouter shorter and more thickly haired; the basal abdominal segment is wider compared with the second and more distinctly separated from it, the second segment itself being of equal breadth at base and apex, whereas in *M. litigiosa* the base of the segment is narrower than the apex; and in *M. buddha* the pygidium is not striolated.

MUTILLA FALLACIOSA, *sp. nov.*

Long. 7-8 mm.

Hab. Trincomali, Ceylon (*Yerbury*).

Similar in form and coloration—black, with the thorax red above, the second abdominal segment with two white round spots, the one behind the other, and the whole of the third segment covered with silvery hair—to *M. constanciæ*, but easily separated by the very roughly tuberculated median segment. Is also not unlike *M. litigiosa* described in this paper, but that has the pleuræ red, the head more coarsely and not so thickly punctured, and the base of the thorax above is not black. Also not unlike *M. dives* Cam., but differs in the tuberculated median

segment, in the densely pilose head, and in the median segment not being so sharply oblique.

Head nearly as wide as the thorax; rugosely punctured; rather thickly covered with longish, silvery and more sparsely with longer, fuscous hairs; the antennal tubercles and the basal half of the mandibles above, rufous; rounded at the sides behind, it being there nearly the length of the eyes; the scape of the antennæ covered with long, silvery hair; the flagellum covered with a close, white down; the third joint is a little, but still distinctly, longer than the fourth. Thorax twice the length of the head; black; the meso- and meta-notum red, except the base and sides of the former; the mesonotum coarsely rugosely punctured, sparsely covered with short, depressed, golden hairs; the median segment with a rounded slope, almost oblique towards the apex, where it is black; coarsely reticulated; the base coarsely tuberculated, the tubercles largest in the middle. The sides of the thorax above almost straight, rough; the eyes bearing very long, blackish hairs. The pleuræ above rugosely punctured; the rest smooth and shining; their lower part thickly covered with long, silvery hair. Legs thickly covered with long, silvery hair; the spines on the hinder tibiæ long, sharp. Abdomen as long as the head and thorax united; deep, velvety black; the basal segment thickly covered with silvery pubescence; there is a spot of silvery pubescence on the second segment in the centre; there is a mark, broader than long, a smaller almost square one in the centre, and the whole of the third segment is covered with silvery pubescence; the segments are also sparsely covered with longish, black hair. Pygidial area longitudinally striolated, rufous in the centre. Petiole beneath with a blunt, slightly curved keel; the second segment somewhat thickly at the apex, and the other ventral segments thickly covered with long, silvery hair.

MUTILLA STULTA, *sp. nov.*

Long. 8 mm. ♀.

Hab. Trincomali, Ceylon (*Yerbury*).

In Bingham's Table, (*l.c.*, p. 5) this species comes in at "b^1. Spot silvery white. b^2. First abdominal segment not ciliated with white hairs. a^3. Second abdominal segment with a transverse band of white pubescence on its apical margin in addition to the spot," but it is very different from *M. decora* Sm., the representative of this section. With *M. trimaculata* it has no near relationship; but, judging from the descriptions, it must be nearly related to *M. coronota* Bingham. It is not *M. stridula* Rossi, *sec.* Rad. = *coronota* Fab., for that has the first segment "armé de dents et carène," which is not the case here; nor has it the pygidial area "ovale, assez grand, finement strié," nor are the tarsi reddish. It is not the *coronota* of Saussure, *Reise der Novara*, *Hymen.* p. 106, who quotes his Ceylonese species as doubtfully identical with *M. coronota* Fab. *M. coronota* Sauss. has the pleuræ "omnis excavata et polita, postice ad marginem leviter rugulata," while in the present species, the pro- and meta-pleuræ, are strongly and coarsely punctured.

Head wider than the thorax; black, the tubercles and the middle of the mandibles broadly rufous; coarsely punctured, the punctures large and deep; there is a distinct keel down the middle of the front; thickly covered with long, fuscous hair; the tubercles large, shining, impunctate, a fine keel between them; over them is a moderately thick, curved keel; behind the eyes the head is obliquely narrowed. Antennæ stout, the scape shining, sparsely covered with longish, pale hairs; the flagellum opaque, covered with a white down. Thorax distinctly narrower than the head, narrowed towards the base and apex; the pro- and meso-notum coarsely longitudinally

punctured, sparsely covered with short, black hair; the median segment has the hair much longer, especially at the base; the base is rounded, the apex oblique and has down its centre a keel; reticulated, the reticulations larger at the base; at the apex of the scutellar region is a transverse keel; and, in the centre of the median segment at the top, is a curved scale-like projection. At the apex of the mesothorax and at the base of the median segment is a small, projecting, roundish tubercle. The propleuræ rather coarsely punctured; the mesopleuræ not much excavated; smooth and shining, except over the middle coxæ, where it is punctured; in the middle on the lower half is a black, curved, oblique furrow; the metapleuræ coarsely punctured behind the oblique furrow. Legs black, thickly covered with pale hair; the tibial spines are few and longish; the spurs pale. Abdomen not much longer than the head and thorax united; a mark of white pubescence on the base of the second segment, which is, at the apex, thickly covered with white hair, forming a broad belt; the penultimate segment covered with long, white hair; the pygidial area smooth, shining, impunctate; the second segment is strongly punctured. Petiole beneath more or less piceous, the apical parts bluntly keeled; the apex itself obliquely pointed, the second ventral segment coarsely punctured, sparsely covered with short, white hair; a reddish transverse band before the apex; the third and following segments covered with long, white hair; the apices of the other segments including the last) strongly punctured.

SCOLIIDÆ.

TIPHIA FULVOHIRTA, *sp. nov.*

Long 8 mm. ♂.

Hab. Poona (*Broughton*).

In Bingham's table (*l.c.*, p. 57) this species comes into the

section: "Wings hyaline or flavo-hyaline: b^3. Median segment with three longitudinal carinæ; a^4. Clypeus incised at apex:"

> The area on the median segment nearly as broad as long: the metapleuræ with only 8 semi-oblique keels at the top; apex of abdomen not densely covered with fulvous hair. *T. incisa* Cam.
>
> The area on the median segment distinctly longer than broad: the metapleuræ strongly obliquely striolated all over, with much more than eight keels, the apical abdominal segments densely covered with fulvous hair. *T. fulvohirta.*

Head shining, rather thickly covered with longish fuscous hair, above the antennæ closely rugose, the front and vertex with large, deep punctures, which are more numerous and closer together near the eyes; the clypeus, except at the apex, closely punctured, thickly covered with long, white hair; the apex in the middle smooth, and shining, and with a wide, distinct incision. Mandibles black, towards the apex broadly rufous: covered with long, white hair; the palpi testaceous. Antennæ stout, the scape strongly punctured, covered with longish, fuscous hair; the flagellum fuscous beneath, almost glabrous. Pronotum in front shining, the base impunctate, the rest of it covered with large, distinctly separated punctures, except a broad impunctate band on the apex; mesonotum with the punctures larger and more widely separated than on the pronotum; the scutellum punctured like the mesonotum, but with the punctures more widely separated; the post-scutellum punctured like the scutellum, but with the punctures smaller. The central area on the median segment with two keels: the space inside them transversely, rugosely punctured, except for a small shining depression at the apex; the inner side of the lateral areæ rugose, the outer aciculated; the apex crenulated; the

apex of the segment has an oblique slope and is closely rugosely punctured. The base of the propleuræ aciculated longitudinally, the upper part with large, deep punctures; the apex, except at the top, closely longitudinally striated, this part being separated from the rest by a curved furrow; the lower part, under the larger punctures, smooth, impunctate. Mesopleuræ strongly punctured, except immediately under the wings, where there is a small impunctate space, separated from the rest by a deep, wide, curved furrow. Legs thickly covered with long, white hair; the fore knees, tibiæ and tarsi more or less rufous. Wings hyaline, with a decided greyish-fuscous tinge towards the apex; the stigma black, the nervures fuscous. Petiole shining, marked with scattered punctures, the apex, especially in the middle, almost impunctate; the second segment punctured, except in the middle towards the apex; its base obliquely depressed: the third and following segments opaque, closely and strongly punctured, thickly covered with long, pale fulvous hair. The ventral segments punctured, the punctures becoming smaller and more numerous towards the apex; the last segment with an impunctate line down the centre.

The rufous colour on the fore legs is not a specific character in this, or in the allied species, as the amount of it varies considerably. The same remark applies to the quantity of rufous or brownish in the colour of the antennæ. There is no trace of a central keel on the median segment in the present species.

Tiphia tarsata Cam. and *T. magretti* Cam. are omitted by Bingham; so also is *T. femorata* Fab., a European species recorded by Magretti, from Burma (*Ann. Mus. Civ. Genova*, (2) xii., 248).

MYZINE BENGALENSIS, *sp. nov.*

Long. 15 mm. ♀.

Hab. Poona, Bengal (*Wroughton*).

Bingham (*l.c.*, p. 65) has been unable to assign the males of the Indian species to their respective females, and describes 7 males and 7 females as distinct species. Doubtless direct observation will be necessary to unite the sexes correctly; and, in default of this information, there is no course open but to treat them as distinct species. Of males, no species is described with red on the abdomen; but of females, there are three with the abdomen red wholly or in part. Of these the present species comes nearest to *M. mandalensis* Magretti, but that has segments 1-5 of the abdomen red and both wings hyaline at the base, the anal segments fuscous, the posterior wings "hyaline, the extreme apex somewhat fuscescent," the tegulæ flavo-testaceous, and, in length, it is only 9-10 mm.

Head shining, rather thickly covered with long, white hair; the vertex with scattered punctures, except in the centre behind the ocelli; the ocellar region being also without punctures; the front more closely and strongly punctured; the clypeus strongly punctured except the apex; its middle carinate. Mandibles black, slightly rufous in the middle; the palpi dark testaceous. Scape of antennæ shining, sparsely covered with long, pale fulvous hair, and with large, deep punctures; the second joint also shining and punctured; the flagellum opaque, thinly covered with a pale down, the under side brownish; the basal joints produced on the under side beneath. The base of the pronotum transversely aciculate; the apex bearing all over large, deep punctures, and sparsely covered with long, pale fulvous hair. Mesonotum shining, having some large, deep punctures; and a deep, wide inner and a much narrower outer furrow on its apical two-thirds. Scutellum shining, its sides and apex bordered with large,

deep punctures; near the centre there is one distinct row and a few other punctures. Post-scutellum shining and slightly punctured in the middle; the sides strongly aciculated. Median segment strongly aciculated, the apex with the sides closely transversely striated; down the centre at the base are two flat, irregular keels. Propleuræ punctured; the apex closely obliquely striolated except at the top, which is punctured; the metapleuræ stoutly obliquely striolated; the upper part closely and finely at the base above. The coxæ and femora shining, sparsely covered with long, white hair, this being also the case with the fore tibiæ and tarsi; the four hinder tibiæ very thickly covered with stiff, white hair; their calcaria pale fulvous; the tarsal hairs silvery, their spines pale fulvous. Wings violaceous, the base of the hinder pair hyaline. Abdomen ferruginous, the two apical segments black; the sides and apex rather thickly covered with long, white hair; the basal segment with shallow, widely separated punctures; the other segments with the punctures fewer in number and more widely separated; the pygidium coarsely punctured, except at the apex, which is pale yellow, dull rufous behind; the ventral surface covered, not very thickly, with long, white hair.

A smaller species than *M. violaceipennis*, to which it is closely allied; but from which it is very distinct, differing greatly in the sculpture of the thorax, the pronotum in *M. violaceipennis* being very coarsely longitudinally striolated, and the scutellum very coarsely punctured; while in the present species those parts bear only scattered punctures; the punctures on the head are also fewer, and neither so large nor so deep.

MYZINE VIOLACEIPENNIS, *sp. nov.*

Long. 19-20 mm. ♀.

Hab. Poona, Bombay (*Wroughton*)

In Bingham's table (*l.c.*, p. 65), it comes in at "*a*[1]. Black, 2nd, 3rd, and base of 4th abdominal segment red, hind wings hyaline at base."

Which will now have to be sub-divided, as the terms will apply to two species.

1. Mesonotum rugose, post-scutellum and median segment smooth and shining. *M. madraspatana* Sm.

2. Mesonotum smooth, except for a few large, scattered punctures at the apex; post-scutellum rugose, with a few large punctures in the middle; the median segment opaque, uniformly finely rugose. *M. violaceipennis.*

Head black, shining; the middle of the vertex with a large, smooth space, except for four small punctures placed in a curve in front of a large, deep one; the rest of the front and vertex with large, deep, widely separated punctures, being, if anything, larger and distinctly more numerous over the antennæ, clypeus coarsely punctured, except at the extreme apex; the middle not carinate, mandibles entirely black, fringed with long, pale golden hair; the palpi dark testaceous. First and second joints of the antennæ shining, bearing some large, deep punctures; the flagellum pruinose, the microscopic pile giving it a whitish appearance. The base of the pronotum transversely coarsely aciculated; the vertical part smooth, impunctate; the basal part very coarsely rugose, the punctures very large, deep and elongated, running more or less into each other; mesonotum smooth and shining; on its apical half are a few large, deep, oval and round punctures; on the apical half there is, on each side, a narrow but distinct furrow. Scutellum very coarsely and deeply punctured all over; post-scutellum coarsely aciculated at the sides; its centre with a few moderately large punctures, median segment coarsely aciculated, opaque, the sides of the basal part obscurely transversely striated; the apex sharply oblique, its sides punctured, but not strongly; down the middle of the basal part runs a straight furrow,

slightly narrowed towards the apex; its sides bordered by sharp keels, its centre with stout transverse keels. Propleuræ strongly punctured at the base; the apical half strongly longitudinally striated; the mesopleuræ coarsely punctured, except at the apex; the metapleuræ strongly closely obliquely striated all over. Wings uniformly deeply violaceous, except the hinder pair at the base. Legs entirely black, shining, the femora sparsely covered with long, pale hair; the outer side of the hind tibiæ thickly covered with white hair and more sparsely with thick, pale fulvous spines; on the apex of the posterior tibiæ on the inner side is a thick patch of depressed, pale hair, and in front of the calcaria are four stout, pale fulvous spines; the calcaria pale fulvous: the tarsal spines rufous. Abdomen shining, smooth: the petiole black, except at the apex, which is red like the 2nd, 3rd, and the basal three-fourths of the 4th segment. The pygidium coarsely irregularly longitudinally striolated, the striæ becoming smaller and less distinct towards the apex; its sides bear long, pale hairs. The ventral segments are coloured like the dorsal; the third, fourth, and fifth finely punctured at the base and apex: their middle with some large punctures; the sixth with the punctures fewer and more scattered.

POMPILIDÆ.

POMPILUS ICHNEUMONIFORMIS Cam.

This is probably the species described by Bingham (*l.c.*, p. 110), as *Pseudagenia deceptrix* Sm. The two in my opinion are not identical, and my type does not agree with Smith's now in the Oxford Museum). *P. deceptrix* is from Celebes.

SPHEGIDÆ.

LARRADA EXTENSA Walker.

This species is omitted by Bingham. It is from Ceylon. (*Cf. Ann. Mag. Nat. Hist.*, Vol. v. (1860), p. 305.)

SPHEX ROTHNEYI Cam.

Bingham regards this as identical with *Sphex vicinus* Lep., a species very badly described, and placed by Kohl in his Monograph among the unidentifiable species. *S. rothneyi* is, however, very probably only a local form of *Sphex pruinosus* Germar, a species recorded from South Eastern Europe, Western Asia, and North Africa (Syria, Caucasus, Soudan). If the two be identical *S. pruinosus* has a very wide range, as have a few other species of the same genus.

SPHEX XANTHOPTERUS Cam.

When I described this species as new (*Manch. Mem.*, (4) ii., p. 109) I was quite justified in doing so, as no such species had been recorded from the old world, and my name has been adopted by Kohl and Bingham. Kohl, however, has since (*Ann. k.k. Hofmus. Wien*, x., p. 52) recognized it, by an examination of the type in the Berlin Museum, as the same as *Sphex cinerascens* Dahlbom (*Hym. Eur.*, i., pp. 25 and 436). From this it follows that the American locality given by Dahlbom must have been erroneous.

SPHEX FLAVOVESTITUS Sm.

This Indian species is omitted by Bingham. The description (*Cat. Hym. Ins. Brit. Mus.*, iv., p. 253) is not very satisfactory; but, as the type is in the British Museum, an examination of it would either establish its specific distinctness, or give it decent burial in the synonomy.

SPHEX DEPLANATUS Kohl.

This species is omitted by Bingham. The following is Kohl's description (*Ann. k.k. Hofmus. Wien*, x., p. 53).

"♂. *Niger; abdomen ex parte rufum. Pedes nigri. Alæ infuscatæ violaceo-resplendentes. Caput et thorax*

albopilosa, segmentum medianum supra albo-villosa. Clypeus pubescentia argenteo-alba adpressa. Oculorum margines interiores ad verticem longitudine flagelli articuli 2^{di} + *duarum tertiarum* 3^{tii} *ad clypeum paullulo minus approximati sunt. Scutellum haud convexum, fere deplanatum. Post-scutellum non sellæ instar ut in* Sph. aurulento *impressum. Area dorsalis segmenti mediani rugis quinque transverse rugosa. Petiolus aliquantum brevior est quam in* Sph. aurulento *F., multo brevior quam in* Sph. pruinoso *G.: longitudine antennarum flagelli articulo secundo æqualis; paullulum brevior tarsi postici secundi, sed paullulo longior tertio.*"

Long. 20 mm.

Hab. Ceylon.

Allied to *S. pruinosus* and *S. aurulentus.*

ALYSON RUFICOLLE, *sp. nov.*

Nigrum, prothorace, mesonoto cum scutello mesopleurisque rufis, ore flagelloque antennarum subtus flavis; alis hyalinis, nervis fuscis. ♂.

Long. fere 5 mm.

Hab. Kandy, Ceylon (*Yerbury*).

Head black; a line on the inner orbits of the eyes from near the top, labrum, clypeus, mandibles, and palpi, yellow; the tips of the mandibles black; front and vertex closely punctured, thickly covered with black hair; the clypeus and mandibles with much longer white hair. Pro- and meso-notum closely, but not strongly, punctured; the prothorax entirely, except a black mark on the base in front, the mesonotum with the scutellum and post-scutellum and the mesopleuræ, red; the median segment with two stout converging (but not uniting) keels in the centre, inside of which are two oblique keels, which unite to them shortly beyond the middle of the basal region; inside of these there are some stout transverse keels,

except at the apex; the apex is rounded; down the middle is a straight stout keel; across the middle a stout, transverse one. at the side of this are two short, curved, irregular keels; at the apex itself there is, on each side, a stout, oblique keel. The base of the propleurae distinctly aciculated; in the centre of the mesopleurae is a wide, moderately deep, oblique depression. Legs black; the apex of the anterior coxae white; the anterior knees, tibiae and tarsi pale testaceous; the apex of the posterior coxae, the apex of the trochanters and a broad band near the apex of the tibiae, testaceous; the extreme apex of the hinder femora and its large tooth, piceous. Wings hyaline, but with a faint fuscous tint; the nervures fuscous; the recurrent nervures interstitial; abdomen shining, impunctate; the maculae large, pallid yellow.

A very distinct species from *A. annulipes*, being readily known from it by the red collar, and by the absence of a fascia in the anterior wings.

DIODONTUS GENICULATUS, *sp. nov.*

Niger, nitidus, segmento mediano striolato; mandibulis tegulisque flavis; basi tibiarum testaceo; alis hyalinis, nervis fuscis, stigmate nigro. ♀.

Long. 4-5 mm.

Hab. Mussooree, 6,000 ft. (*Rothney*).

Comes near to *D. striolatus* Cam. from Lahore (*Manchester Memoirs, xli., p. 19*), but readily separated from it by the pro- and meso-pleurae not being striated, by the four hinder tibiae being black, except at the base, and by the strongly transversely and longitudinally striolated median segment.

Head large, wider than the thorax; almost shining, bearing some shallow, not very distinct, punctures; the front and vertex with a sparse, microscopic black pile; the oral region with a silvery pubescence and with long, white,

soft hairs; the clypeus with a small tooth on either side, the centre not being incised. Mandibles large; the basal half yellow; the apical piceous; the palpi dirty yellow; antennæ entirely black; the scape shining, bare, impunctate; the flagellum covered with a microscopic down; the third and fourth joints equal in length. Thorax shining, glabrous, except for a very slight microscopic pile; the median segment strongly aciculated, and with six longish, and three very short, irregular, longitudinal keels in the centre, the lateral pairs being united at the apices by a curved keel; the apex has an oblique slope, is irregularly transversely striated and has an elongated fovea in the middle; it is closely covered with a short, fuscous pile. Pro- and meta-pleuræ shining; the mesopleuræ shagreened; the metapleuræ with a few oblique, not very distinct, keels. Wings clear hyaline; the second cubital cellule half as long at the top as it is at the bottom; the second recurrent nervure is received very shortly beyond the middle of the cellule. Legs stout, covered with a white pubescence; the tarsi more or less rufo-testaceous; the base of all the tibiæ testaceous all round; and the anterior more or less testaceous in front; the hinder pair only testaceous at the base and bearing fine stout spines. Abdomen somewhat shorter than the head and thorax united, shining, pruinose; the pygidial area strongly aciculated; the sides distinctly keeled.

PASSALOECUS RETICULATUS, *sp. nov.* Pl. 4, fig. 2.

Nigro-caeruleus; geniculis, tibiis tarsisque testaceis, alis hyalinis, stigmate fusco, nervis pallide flavis. ♀.

Long. 5 mm.

Hab. Barrackpore (*Rothney*).

Head shining, apparently bare; black with a greenish hue; the front broadly hollowed; the hollow bordered by a stout keel, which originates in the front of the anterior

ocellus, where it bifurcates: from the side of the fore ocellus a narrower keel runs to the side, uniting with the larger keel before the eyes: the space between the keel and the eyes is stoutly crenulated. On the upper half of the eyes, but not touching them, is a narrow furrow; behind, on the upper half is a much wider. deeper, crenulated furrow; the lower part of the eyes on the inner and apical side is distinctly margined by a keel. Antennæ black, the scape slightly, the flagellum broadly, testaceous beneath. Thorax black, with a greenish tinge; the mesonotum shagreened; a fine transverse furrow at the base of the scutellum; down the centre of the mesonotum are two wide furrows which slightly converge towards the scutellum and are, towards the apex, slightly crenulated; in the centre are two obscure longitudinal furrows; and, outside the central, there are two narrower, complete furrows, which are distinctly curved towards the base of the thorax. At the base of the scutellum there is a wide, deep, straight furrow behind the narrower one. Scutellum large, indistinctly keeled down the middle; the sides straight, distinctly margined; post-scutellum distinct; the sides obliquely truncated towards the apex. Median segment with a decided coppery-greenish tint; the base completely areolated; all the areæ being distinctly defined; the middle portion is entirely occupied by a deep pentagonal area, wider than long and, of which, the apex is rounded inwardly; down its centre is a narrow furrow, and near its apex are two stout, transverse, somewhat curved keels; the apex itself is perpendicular and transversely roughened. In front of the tegulæ are two or three stout keels, and inside of these a few large, round punctures. Wings clear hyaline, the stigma fuscous, paler above; the costa in front of it fuscous, the rest of it and the nervures yellow; the second cubital nervure narrowed on the lower side; the second recurrent nervure almost interstitial. Femora sparsely

covered with white hair ; the trochanters, apex of femora, tibiæ, and tarsi rufo-testaceous. Petiole as long as the hinder coxæ ; coarsely shagreened, the sides distinctly margined ; beneath, it is prolonged to the apex of the second segment ; the base of the third segment being obliquely truncated beneath, it forms, with the apex of the petiole, a wide, triangular incision. The rest of the abdomen smooth and shining ; the apex without a pygidial area.

In some respects this species is intermediate between *Pemphredon* and *Passaloecus*, its petiole being longer than it is in the latter, but much shorter than in the former, from which it further differs in the hinder tibiæ not being spined ; in the head not being covered with long hair ; in the margined eyes, in the vertex and hollowed front bearing keels ; and in the median segment having keels which form large distinct areæ, the lower part of the segment, too, being largely and deeply hollowed. The labrum is not emarginate at the apex, so far as I can make out from the dense silvery pubescence which covers the mouth ; the mandibles are large, not furrowed ; oblique at the apex, where there is one large, acute tooth, and a much smaller and blunter one, next to it. The eyes reach to the base of the mandibles and are parallel ; the antennæ are situated quite close to the base of the clypeus, but not touching it ; the transverse basal nervure is interstitial ; on the mesopleuræ there is one distinct, moderately wide and deep, complete, longitudinal furrow. The second cubital cellule is much narrower than it is in either *Pemphredron* or *Passaloecus* proper, and is much narrowed on the lower side ; the stigma is large ; the radial cellule elongate, lanceolate ; in the female, there is no pygidial area. The tubercules do not reach to the tegulæ.

This species, having only one longitudinal furrow on the mesopleuræ, is a *Passaloecus* as limited by Verhoeff (*Ent.*

MYZINE BENGALENSIS, *sp. nov.*

Long. 15 mm. ♀.

Hab. Poona, Bengal (*Wroughton*).

Bingham (*l.c.*, p. 65) has been unable to assign the males of the Indian species to their respective females, and describes 7 males and 7 females as distinct species. Doubtless direct observation will be necessary to unite the sexes correctly; and, in default of this information, there is no course open but to treat them as distinct species. Of males, no species is described with red on the abdomen; but of females, there are three with the abdomen red wholly or in part. Of these the present species comes nearest to *M. mandalensis* Magretti, but that has segments 1-5 of the abdomen red and both wings hyaline at the base, the anal segments fuscous, the posterior wings "hyaline, the extreme apex somewhat fuscescent," the tegulæ flavo-testaceous, and, in length, it is only 9-10 mm.

Head shining, rather thickly covered with long, white hair; the vertex with scattered punctures, except in the centre behind the ocelli; the ocellar region being also without punctures; the front more closely and strongly punctured; the clypeus strongly punctured except the apex; its middle carinate. Mandibles black, slightly rufous in the middle; the palpi dark testaceous. Scape of antennæ shining, sparsely covered with long, pale fulvous hair, and with large, deep punctures; the second joint also shining and punctured; the flagellum opaque, thinly covered with a pale down, the under side brownish; the basal joints produced on the under side beneath. The base of the pronotum transversely aciculate; the apex bearing all over large, deep punctures, and sparsely covered with long, pale fulvous hair. Mesonotum shining, having some large, deep punctures; and a deep, wide inner and a much narrower outer furrow on its apical two-thirds. Scutellum shining, its sides and apex bordered with large,

deep punctures; near the centre there is one distinct row and a few other punctures. Post-scutellum shining and slightly punctured in the middle; the sides strongly aciculated. Median segment strongly aciculated, the apex with the sides closely transversely striated; down the centre at the base are two flat, irregular keels. Propleuræ punctured; the apex closely obliquely striolated except at the top, which is punctured; the metapleuræ stoutly obliquely striolated; the upper part closely and finely at the base above. The coxæ and femora shining, sparsely covered with long, white hair, this being also the case with the fore tibiæ and tarsi; the four hinder tibiæ very thickly covered with stiff, white hair; their calcaria pale fulvous; the tarsal hairs silvery, their spines pale fulvous. Wings violaceous, the base of the hinder pair hyaline. Abdomen ferruginous, the two apical segments black; the sides and apex rather thickly covered with long, white hair; the basal segment with shallow, widely separated punctures; the other segments with the punctures fewer in number and more widely separated; the pygidium coarsely punctured, except at the apex, which is pale yellow, dull rufous behind; the ventral surface covered, not very thickly, with long, white hair.

A smaller species than *M. violaceipennis*, to which it is closely allied; but from which it is very distinct, differing greatly in the sculpture of the thorax, the pronotum in *M. violaceipennis* being very coarsely longitudinally striolated, and the scutellum very coarsely punctured; while in the present species those parts bear only scattered punctures; the punctures on the head are also fewer, and neither so large nor so deep.

MYZINE VIOLACEIPENNIS, *sp. nov.*

Long. 19-20 mm. ♀.

Hab. Poona, Bombay (*Wroughton*).

In Bingham's table (*l.c.*, p. 65), it comes in at "a^1. Black, 2nd, 3rd, and base of 4th abdominal segment red, hind wings hyaline at base."

Which will now have to be sub-divided, as the terms will apply to two species.

1. Mesonotum rugose, post-scutellum and median segment smooth and shining. *M. madraspatana* Sm.

2. Mesonotum smooth, except for a few large, scattered punctures at the apex; post-scutellum rugose, with a few large punctures in the middle; the median segment opaque, uniformly finely rugose. *M. violaceipennis.*

Head black, shining; the middle of the vertex with a large, smooth space, except for four small punctures placed in a curve in front of a large, deep one; the rest of the front and vertex with large, deep, widely separated punctures, being, if anything, larger and distinctly more numerous over the antennæ, clypeus coarsely punctured, except at the extreme apex; the middle not carinate, mandibles entirely black, fringed with long, pale golden hair; the palpi dark testaceous. First and second joints of the antennæ shining, bearing some large, deep punctures; the flagellum pruinose, the microscopic pile giving it a whitish appearance. The base of the pronotum transversely coarsely aciculated; the vertical part smooth, impunctate; the basal part very coarsely rugose, the punctures very large, deep and elongated, running more or less into each other; mesonotum smooth and shining; on its apical half are a few large, deep, oval and round punctures; on the apical half there is, on each side, a narrow but distinct furrow. Scutellum very coarsely and deeply punctured all over; post-scutellum coarsely aciculated at the sides; its centre with a few moderately large punctures, median segment coarsely aciculated, opaque, the sides of the basal part obscurely transversely striated; the apex sharply oblique, its sides punctured, but not strongly; down the middle of the basal part runs a straight furrow,

slightly narrowed towards the apex ; its sides bordered by sharp keels, its centre with stout transverse keels. Propleuræ strongly punctured at the base ; the apical half strongly longitudinally striated ; the mesopleuræ coarsely punctured, except at the apex ; the metapleuræ strongly closely obliquely striated all over. Wings uniformly deeply violaceous, except the hinder pair at the base. Legs entirely black, shining, the femora sparsely covered with long, pale hair ; the outer side of the hind tibiæ thickly covered with white hair and more sparsely with thick, pale fulvous spines ; on the apex of the posterior tibiæ on the inner side is a thick patch of depressed, pale hair, and in front of the calcaria are four stout, pale fulvous spines ; the calcaria pale fulvous : the tarsal spines rufous. Abdomen shining, smooth : the petiole black, except at the apex, which is red like the 2nd, 3rd, and the basal three-fourths of the 4th segment. The pygidium coarsely irregularly longitudinally striolated, the striæ becoming smaller and less distinct towards the apex ; its sides bear long, pale hairs. The ventral segments are coloured like the dorsal ; the third, fourth, and fifth finely punctured at the base and apex : their middle with some large punctures ; the sixth with the punctures fewer and more scattered.

POMPILIDÆ.

POMPILUS ICHNEUMONIFORMIS Cam.

This is probably the species described by Bingham (*l.c.*, p. 110), as *Pseudagenia deceptrix* Sm. The two in my opinion are not identical, and my type does not agree with Smith's now in the Oxford Museum). *P. deceptrix* is from Celebes.

SPHEGIDÆ.

LARRADA EXTENSA Walker.

This species is omitted by Bingham. It is from Ceylon. (*Cf. Ann. Mag. Nat. Hist.*, Vol. v. (1860), p. 305.)

SPHEX ROTHNEYI Cam.

Bingham regards this as identical with *Sphex vicinus* Lep., a species very badly described, and placed by Kohl in his Monograph among the unidentifiable species. *S. rothneyi* is, however, very probably only a local form of *Sphex pruinosus* Germar, a species recorded from South Eastern Europe, Western Asia, and North Africa (Syria, Caucasus, Soudan). If the two be identical *S. pruinosus* has a very wide range, as have a few other species of the same genus.

SPHEX XANTHOPTERUS Cam.

When I described this species as new (*Manch. Mem.*, (4) ii., p. 109) I was quite justified in doing so, as no such species had been recorded from the old world, and my name has been adopted by Kohl and Bingham. Kohl, however, has since (*Ann. k.k. Hofmus. Wien*, x., p. 52) recognized it, by an examination of the type in the Berlin Museum, as the same as *Sphex cinerascens* Dahlbom (*Hym. Eur.*, i., pp. 25 and 436). From this it follows that the American locality given by Dahlbom must have been erroneous.

SPHEX FLAVOVESTITUS Sm.

This Indian species is omitted by Bingham. The description (*Cat. Hym. Ins. Brit. Mus.*, iv., p. 253) is not very satisfactory; but, as the type is in the British Museum, an examination of it would either establish its specific distinctness, or give it decent burial in the synonomy.

SPHEX DEPLANATUS Kohl.

This species is omitted by Bingham. The following is Kohl's description (*Ann. k.k. Hofmus. Wien*, x., p. 53).

"♂. *Niger; abdomen ex parte rufum. Pedes nigri. Alæ infuscatæ violaceo-resplendentes. Caput et thorax*

longer than the fourth. Head black; alutaceous, the vertex covered with a dark, microscopic down; the front deeply excavated; thickly covered with depressed, silvery pubescence, as is also the clypeus; the frontal depression at the top with a distinctly-defined margin, the centre of which, looked at from beneath, is slightly curved; the eyes on the upper part on the inner side are slightly margined; below the middle is a small, human-ear-shaped fovea; the ocelli are in a curve. Mandibles lemon-yellow; the apex piceous-black; the basal part sparsely covered with long, white hairs. Mesonotum alutaceous, thickly covered with a microscopic, fuscous down; the pronotum with longer, fuscous hair; the scutellum like the mesonotum, its apex with some longitudinal striæ, and a thin keel runs down its middle; on its base at the side is a small, and, behind this, a larger, transverse yellow mark; the post-scutellum finely rugose; coarsely longitudinally striolate. Median segment with a rounded slope; the basal area clearly defined; bearing a few oblique, widely separated keels; those at the sides being more distinct than those in the middle and extend beyond the area, outside of which the segment is closely, but not very distinctly, punctured; the middle of the apical part has a wide, deep furrow The propleuræ at the top have a few fine, indistinct striæ, the lower part in the centre has a few stout, longitudinal striæ. The tubercles are yellow; the oblique furrow behind them straight, narrow; the longitudinal furrow narrow, shining; the oblique furrow on the mesopleuræ wide, deep, indistinctly crenulated; the apical semi-vertical furrow wider, deeper, and distinctly crenulated; the metapleuræ at the base shining, strongly closely obliquely striated, the rest of it finely and closely longitudinally striated, the striæ stronger on the lower side. Legs: the apices of the coxæ, of the femora, and the tibiæ lemon-yellow; the tibiæ for the greater part black beneath; the

except at the apex; the apex is rounded; down the middle is a straight stout keel; across the middle a stout, transverse one, at the side of this are two short, curved, irregular keels; at the apex itself there is, on each side, a stout, oblique keel. The base of the propleuræ distinctly aciculated; in the centre of the mesopleuræ is a wide, moderately deep, oblique depression. Legs black; the apex of the anterior coxæ white; the anterior knees, tibiæ and tarsi pale testaceous; the apex of the posterior coxæ, the apex of the trochanters and a broad band near the apex of the tibiæ, testaceous; the extreme apex of the hinder femora and its large tooth, piceous. Wings hyaline, but with a faint fuscous tint; the nervures fuscous; the recurrent nervures interstitial; abdomen shining, impunctate; the maculæ large, pallid yellow.

A very distinct species from *A. annulipes*, being readily known from it by the red collar, and by the absence of a fascia in the anterior wings.

DIODONTUS GENICULATUS, *sp. nov.*

Niger, nitidus, segmento mediano striolato; mandibulis tegulisque flavis; basi tibiarum testaceo; alis hyalinis, nervis fuscis, stigmate nigro. ♀.

Long. 4-5 mm.

Hab. Mussooree, 6,000 ft. (*Rothney*).

Comes near to *D. striolatus* Cam. from Lahore (*Manchester Memoirs, xli., p. 19*), but readily separated from it by the pro- and meso-pleuræ not being striated, by the four hinder tibiæ being black, except at the base, and by the strongly transversely and longitudinally striolated median segment.

Head large, wider than the thorax; almost shining, bearing some shallow, not very distinct, punctures; the front and vertex with a sparse, microscopic black pile; the oral region with a silvery pubescence and with long, white,

soft hairs; the clypeus with a small tooth on either side, the centre not being incised. Mandibles large; the basal half yellow; the apical piceous; the palpi dirty yellow; antennæ entirely black; the scape shining, bare, impunctate; the flagellum covered with a microscopic down; the third and fourth joints equal in length. Thorax shining, glabrous, except for a very slight microscopic pile; the median segment strongly aciculated, and with six longish, and three very short, irregular, longitudinal keels in the centre, the lateral pairs being united at the apices by a curved keel; the apex has an oblique slope, is irregularly transversely striated and has an elongated fovea in the middle; it is closely covered with a short, fuscous pile. Pro- and meta-pleuræ shining; the mesopleuræ shagreened; the metapleuræ with a few oblique, not very distinct, keels. Wings clear hyaline; the second cubital cellule half as long at the top as it is at the bottom; the second recurrent nervure is received very shortly beyond the middle of the cellule. Legs stout, covered with a white pubescence; the tarsi more or less rufo-testaceous; the base of all the tibiæ testaceous all round; and the anterior more or less testaceous in front; the hinder pair only testaceous at the base and bearing fine stout spines. Abdomen somewhat shorter than the head and thorax united, shining, pruinose; the pygidial area strongly aciculated; the sides distinctly keeled.

PASSALOECUS RETICULATUS, *sp. nov.* Pl. 4, fig. 2.

Nigro-caeruleus; geniculis, tibiis tarsisque testaceis, alis hyalinis, stigmate fusco, nervis pallide flavis. ♀.

Long. 5 mm.

Hab. Barrackpore (*Rothney*).

Head shining, apparently bare; black with a greenish hue; the front broadly hollowed; the hollow bordered by a stout keel, which originates in the front of the anterior

ocellus, where it bifurcates; from the side of the fore ocellus a narrower keel runs to the side, uniting with the larger keel before the eyes; the space between the keel and the eyes is stoutly crenulated. On the upper half of the eyes, but not touching them, is a narrow furrow; behind, on the upper half is a much wider, deeper, crenulated furrow; the lower part of the eyes on the inner and apical side is distinctly margined by a keel. Antennæ black, the scape slightly, the flagellum broadly, testaceous beneath. Thorax black, with a greenish tinge; the mesonotum shagreened; a fine transverse furrow at the base of the scutellum; down the centre of the mesonotum are two wide furrows which slightly converge towards the scutellum and are, towards the apex, slightly crenulated; in the centre are two obscure longitudinal furrows; and, outside the central, there are two narrower, complete furrows, which are distinctly curved towards the base of the thorax. At the base of the scutellum there is a wide, deep, straight furrow behind the narrower one. Scutellum large, indistinctly keeled down the middle; the sides straight, distinctly margined; post-scutellum distinct; the sides obliquely truncated towards the apex. Median segment with a decided coppery-greenish tint; the base completely areolated; all the areæ being distinctly defined; the middle portion is entirely occupied by a deep pentagonal area, wider than long and, of which, the apex is rounded inwardly; down its centre is a narrow furrow, and near its apex are two stout, transverse, somewhat curved keels; the apex itself is perpendicular and transversely roughened. In front of the tegulæ are two or three stout keels, and inside of these a few large, round punctures. Wings clear hyaline, the stigma fuscous, paler above; the costa in front of it fuscous, the rest of it and the nervures yellow; the second cubital nervure narrowed on the lower side; the second recurrent nervure almost interstitial. Femora sparsely

covered with white hair ; the trochanters, apex of femora, tibiæ, and tarsi rufo-testaceous. Petiole as long as the hinder coxæ ; coarsely shagreened, the sides distinctly margined ; beneath, it is prolonged to the apex of the second segment ; the base of the third segment being obliquely truncated beneath, it forms, with the apex of the petiole, a wide, triangular incision. The rest of the abdomen smooth and shining ; the apex without a pygidial area.

In some respects this species is intermediate between *Pemphredon* and *Passaloecus*, its petiole being longer than it is in the latter, but much shorter than in the former, from which it further differs in the hinder tibiæ not being spined ; in the head not being covered with long hair ; in the margined eyes, in the vertex and hollowed front bearing keels ; and in the median segment having keels which form large distinct areæ, the lower part of the segment, too, being largely and deeply hollowed. The labrum is not emarginate at the apex, so far as I can make out from the dense silvery pubescence which covers the mouth ; the mandibles are large, not furrowed ; oblique at the apex, where there is one large, acute tooth, and a much smaller and blunter one, next to it. The eyes reach to the base of the mandibles and are parallel ; the antennæ are situated quite close to the base of the clypeus, but not touching it ; the transverse basal nervure is interstitial ; on the mesopleuræ there is one distinct, moderately wide and deep, complete, longitudinal furrow. The second cubital cellule is much narrower than it is in either *Pemphredon* or *Passaloecus* proper, and is much narrowed on the lower side ; the stigma is large ; the radial cellule elongate, lanceolate ; in the female, there is no pygidial area. The tubercules do not reach to the tegulæ.

This species, having only one longitudinal furrow on the mesopleuræ, is a *Passaloecus* as limited by Verhoeff (*Ent.*

species here described, may be separated as follows, apart from the oral characters noted below.

Black, the base of the abdomen red ; the wings hyaline, abdomen not pedunculate, length, 7—8 mm.
P. pulchellus Sm.

Fulvous, the head, pronotum and apex of abdomen broadly yellow ; wings fulvous ; abdomen pedunculate ; length, 24 mm. *P. fulvipennis.*

Belongs to Saussure's first division : labial palpi large, not plumose, carrying only stiff hairs ; mandibles short ; abdomen pedunculate. Dark rufous : the head, except a transverse stripe on the vertex uniting the eyes, the pronotum, two marks near the apex of the second abdominal segment, and the four apical segments broadly, lemon-yellow; wings fulvo-hyaline, the apex smoky ; the costa and stigma fulvous ; the nervures fuscous.

Antennæ fulvous, the scape lemon-yellow, except at the extreme apex ; bare except for a pale, microscopic down on the apical joints. Head lemon-yellow, shining ; the front and vertex bearing a short, pale pubescence ; a rufous band across the vertex behind the ocelli joining the eyes ; in the middle, it is prolonged to enclose the ocelli, from the sides of which runs a short, oblique line of the same colour. Mandibles dark rufous ; the teeth black ; on their apices are four short, distinct, blunt teeth ; the apical rounded ; the palpi rufo-testaceous ; the hairs long, stiff, pale. Clypeus bare ; bearing scattered, shallow punctures ; the apex with the sides almost straight, oblique ; the centre roundly incised, the incision at the sides ending in somewhat triangular, sharp teeth. Thorax rufous, except for a broad lemon-yellow mark on the pronotum ; the mark does not reach the apex of the segment and is bluntly rounded and narrowed at its apex. Mesonotum with scutellum densely covered with a fuscous, microscopic pile ; at the apex, touching

the scutellum, are two straight, distinct, moderately deep and wide furrows ; and opposite the apex of the tegulæ, but not reaching the scutellum, is a shorter more indistinct furrow. Scutellum flat, shining ; post-scutellum with a rounded slope ; its apex bordered by oblique furrows, which unite at the top with the wider and deeper furrow down the centre of the median segment. Pro- and meso-pleuræ with a few scattered shallow punctures ; shortly behind the middle of the mesopleuræ is an oblique, moderately wide and deep, crenulated furrow, which unites with a narrower oblique crenulated one originating at the base of the mesopleuræ ; from the posterior part of the upper furrow runs a short, much wider and deeper, oblique furrow. At the base of the median segment is a crenulated, slightly oblique furrow, wide at the top, much narrower and more distinctly crenulated at the bottom. In front of the hinder coxæ are two stout teeth ; the hinder being narrower, sharper and longer than the anterior. Metapleuræ smooth, the middle aciculated ; the apex punctured ; the apical half of the median segment being also marked with punctures ; and rather thickly covered with longish, pale hairs. Legs coloured like the body ; the femora sparsely covered with longish, pale hairs ; the tibiæ and tarsi more thickly with pale pubescence. Second cubital cellule much narrowed at the top, being there slightly shorter than the space bounded by the second recurrent and the second transverse cubital nervures. Petiole elongate, slightly, but distinctly, longer than the second segment, becoming gradually wider from the base to the apex ; the apex with distinct punctures ; and having in the centre a deep, short, longitudinal furrow ; the lateral teeth, before the middle, large, triangular. Second segment obscurely punctured ; in front of the middle are two moderately large, transverse marks ; the third segment broadly lemon-yellow at the apex ; the base black, rufous at the sides ;

the fourth segment broadly yellow, a narrow, short, rufous line down the middle at the base, and a rufous mark on each side; the fifth segment broadly yellow, in the middle; the rufous triangularly projecting into it at the sides and at the base in the middle; the last segment broadly yellow; there is a transverse depression at the apex. The sides, base and apex of the lower side of the petiole smooth, impunctate, the rest with stout, slightly curved keels. The second segment, except in the middle, with shallow, rather widely separated, punctures; the other segments much more closely and strongly punctured.

What is no doubt a variety has the apex of the second abdominal segment broadly lemon-yellow, while in its centre, at the base, is a large, somewhat triangular, black mark, the narrow part of which is at the base; its fourth segment is black at the base.

Note.—This species may not be a true *Pterochilus*. The maxillary palpi are 6-jointed as in the typical species; but the labial are distinctly 4-jointed, whereas in *Pterochilus* proper they are 3-jointed only. On the basal joint of the labial palpi there are two or three hairs near the middle; and at the apices of the first, second, and third joints are two or three long, stiff, bristle-like hairs. The fourth joint is bare and is nearly half the length of the third. In addition to the four large apical teeth on the mandibles, there are two small ones and a much larger rounded one.

The number of joints in the labial palpi and their clothing do not appear to be features of generic importance. Saussure says (*Monog. des Guêpes*, iii., p. 321): "On remarque des espèces dont les palpes labiaux sont à peine comprimés et à peine plumeux; on aperçoit même parfois un quatrième article rudimentaire;" but in our species the fourth joint cannot be called "rudimentary," being quite distinct.

ODYNERUS.

ODYNERUS EREBODES, *sp. nov.*

Niger, capite thoraceque distincte punctatis; abdominis segmentis 1-3 pallide flavo-balteatis; pedibus sordide rufis;

basi clypei scapoque antennarum subtus pallide flavis; alis violaceo-fumatis. ♀.

Long. 9 mm.

Hab. Poona *(Wroughton)*.

In Bingham's table (*l.c.*, p. 362) it comes in "a^4. Third abdominal segment with a transverse yellow fascia on the middle of its posterior margin" which may now be subdivided as follows:

Scape of antennæ black; tegulæ yellow, post-scutellum with a yellow spot on the angles, wings clear hyaline. *O. burmanicus* Bing.

Scape of antennæ yellow beneath; tegulæ entirely black; post-scutellum impunctate, wings smoky. *O. erebodes.*

Head coarsely punctured; the punctures large, round and deep; black; a large, curved band on the base of the clypeus, a small, heart-shaped mark between the antennæ, a line along the lower curve of the eye, and two small marks, longer than broad, on the apex of clypeus, pallid yellow; mandibles black, the apex broadly piceous; an elongate, yellow mark in the middle at the base; this mark being sharply pointed at the apex. Palpi testaceous. Clypeus as long as its breadth in the middle; the apex narrowed, the sides oblique; the middle with a shallow, rounded incision, the sides of which form triangular teeth. The clypeus has a few shallow punctures and is densely covered with silvery pubescence. Front and vertex bearing large, deep, distinctly separated punctures; the front very thickly, the vertex more sparsely, covered with silvery pubescence and hairs; the eye orbits, on the lower side behind, thickly covered with silvery pubescence; a little above the middle, there is a small, yellow mark. Antennæ covered with a white down; the scape yellow beneath. Pro- and meso-notum with scutellum bearing all over deep, large punctures, those on the apical part of the mesonotum being the larger; thickly covered with short fuscous pubescence,

the pronotum transverse in front, and bearing two short, yellow lines in the middle; the post-scutellum coarsely rugosely punctured, thickly covered with black hair; the sides oblique, the middle depressed; the median segment with an oblique slope, the centre not excavated; in the middle deeply furrowed. Pleuræ coarsely punctured like the mesonotum, the punctures on the metapleuræ towards the apex running into reticulations. Legs dark rufous; the coxæ blackish; the femora and tibiæ in front blackish; the extreme apices of the femora yellow; the four hinder tibiæ with a yellow line in the middle in front; the tarsi infuscated. The wings are lighter in tint behind and at the base; the nervures and stigma black. Abdomen with the basal segment behind and at the sides, the second with the apex all round and the third with a band in the centre, pale yellow; the basal segment rounded at the base; sparsely punctured; the second segment strongly punctured; the third still more strongly, the puncturing on the other segments becoming gradually weaker; the basal segment yellow, suffused with blood-colour beneath.

ODYNERUS WROUGHTONI, *sp. nov.*

Long. 8 mm.

Hab. Poona (*Wroughton*).

In Bingham's table (*l. c.*, p. 362) it comes in at "a^2. Base of 1st abdominal segment red; a^3. abdomen petiolate" which will now be sub-divided:

> Median segment not reticulated at the base and with a carina on either side; the three apical segments of the abdomen not marked with white in the centre above. *O. miniatus* Sauss.
>
> Median segment reticulated at the base, without a keel on either side; the three apical segments of the abdomen marked with yellow in the middle. *O. wroughtoni.*

The antennæ black; the scape clear yellow; the flagellum brownish beneath; the flagellum bearing a

sparse, white, microscopic pile. Head coarsely punctured, sparsely covered with short, white hair; the hinder ocelli in large deep pits. The centre of the clypeus black, except the apex, which is red; this black and red part coarsely and strongly punctured; the black narrowed at the base and not keeled laterally; but the rest is bordered by distinct, reddish, straight keels which converge slightly towards the apex, which is transverse; its sides, except at the apex, yellow; and punctured on the outer side. Mandibles red, yellow at the base; the palpi yellow; above the antennæ is a yellow mark, mitre-shaped, except that it is roundly produced beneath. Thorax black; two large marks on the middle of the pronotum—narrow at the base, wide, and oblique at the apex, the post-scutellum, and a somewhat pyriform mark, below and in front of the tegulæ, yellow. Pro- and meso-notum with the scutella strongly punctured; the base of the median segment in the centre reticulated, densely covered with white pubescence, especially at the centre of the base, where it almost hides the surface. Pro- and meso-pleuræ strongly punctured, covered with silvery hair; the metapleuræ apparently impunctate, the surface hidden by silvery pubescence. Tegulæ yellow, reddish in middle. Wings hyaline; the nervures and costa blackish; the stigma fuscous; the second cubital cellule at the top narrowed, being there not much wider than the space bounded by the first transverse cubital and the first recurrent nervures. Legs red, the tibiæ yellow on the outside, this being also, to a less extent, the case with the tarsi at the base. Petiole red; yellow at the apex above; shining, punctured towards the apex; the second segment obscurely punctured at the base, more strongly towards the apex; an oval, irregular spot on either side near the apical third; its apex with a moderately broad, yellow band, slightly dilated at the sides, and at the middle; the 3—5 segments

more strongly and closely punctured ; on the apex of the third segment in the middle are two small, yellow marks ; on the fourth segment in the centre is a much larger mark, transverse at the apex, contracted in the middle at the the base and with the sides rounded ; on the apex of the last segment is a larger yellow mark rounded at the base, the apex roundly projecting in the middle. Beneath, the basal segment is red ; the apex of the second, yellow.

VESPIDÆ.

ICARIA JUCUNDA, *sp. nov.*

Long. 15 mm. (worker).

Hab. New Guinea (*Cuthbertson*).

Agrees closely in size, form and coloration with *I. ferruginea ;* but may be known from it by the scutellum and post-scutellum being furrowed down the centre ; by the middle of the median segment being much more strongly and broadly transversely striated, by the petiole being longer, by its narrowed basal half being narrower compared with the apical and more distinctly separated from it ; by the yellow band on the second abdominal segment being much narrower and by the wings being much lighter in tint, their apex being only lightly infuscated.

Several species of *Icaria* are known from New Guinea and the neighbouring Islands ; but the present species does not agree with any of them. Smith's catalogue (*Proc. Linn. Soc.* (*Zool.*), 1869) is not trustworthy. In *Icaria* there are several noteworthy omissions ; *e.g.*, *I. festina* Sm., *I. bicolor* Sm. (*Proc. Linn. Soc.* (*Zool.*), 1864, *p.* 90), from New Guinea, and *I. australis* Sauss , from Dorey.

Rufo-ferruginous ; the apex of the clypeus all round, the base of the mandibles broadly, the edge of the thorax all round in front, scutellum, post-scutellum, two moderately large, oblique marks on the apex of the median

segment, a large mark on the base of the mesopleuræ immediately under the wings, a more obscure one above the middle coxæ, a narrow line on the apex of the petiole and the apical fourth of the second segment above and the apical eighth below, yellow. Head coarsely, but not very distinctly, punctured; the front and vertex sparsely covered with a short, sparse, pale pubescence; the face with the pubescence much thicker and with a fulvous hue; the clypeus covered with long, bright golden hairs. Antennal fovea deeply furrowed in the middle above. Sides of the clypeus straight, oblique, its centre not ending in a point or tooth. Mandibles ferruginous, the teeth black; a large, somewhat triangular, yellow mark on the base above, its apex reaching beyond the middle. Antennæ ferruginous, the scape somewhat darker in tint; the flagellum, especially towards the apex, densely covered with a white down. The edge of the pronotum sharply carinate. Pro- and meso-notum coarsely punctured, running into obscure reticulations towards the apex; the edge of the pronotum narrowly depressed, the depression forming a furrow and black. Scutellum and post-scutellum rather strongly, but not closely, punctured; the central furrow on the scutellum deep, shining, rufo-piceous; that on the post-scutellum broader but not quite so deep. Median segment with an oblique slope; its centre appearing raised through being transversely striated, and bordered by a distinct margin or furrow; the centre at the apex deeply excavated, and with a distinct furrow in the middle. Pro- and meso-pleuræ coarsely punctured. The base of the metapleuræ strongly, coarsely and irregularly longitudinally striated, bordered behind by a black furrow, and below by a short, oblique, shining furrow, from which a curved, not very distinct, furrow runs to the hinder coxæ. Legs ferruginous; the coxæ densely covered with fulvous pile, especially at the base on the under side. Wings hyaline, the costal and

radial cellules smoky; the stigma flavo-testaceous; the nervures blackish. Petiole elongate, the basal third distinctly narrowed and separated from the rest; the narrow yellow apex being also slightly narrowed; shining, impunctate; towards the apex thickly covered with depressed, fulvous hair. The other segments closely and rather strongly punctured, particularly the third and following.

ICARIA CEYLONICA, *sp. nov.*

Long. fere 9 mm. (worker).

Hab. Periyakullam, Ceylon (*Yerbury*).

In Bingham's table (*l.c.*, p. 386), this species can be referred to "A. Reddish or reddish-brown, with yellow markings," and to subsection "*a.* second abdominal segment with no transverse yellow band on its apical margin," which will now be subdivided :—

Head and thorax rufous; abdomen black; hind legs for the greater part black. *I. guttatipennis.*

Entirely rufous, except the second abdominal segment, which is infuscated; legs without black. *I. ceylonica.*

Head reddish, sparsely covered with short, glistening white pubescence; the front and vertex with moderately large, rather widely separated punctures, the ocellar space fuscous; the antennal tubercle bare; furrowed above; the clypeus almost bare at the apex, its sides oblique, the middle ending in a tooth, and with some large punctures; at the base of the mandibles is a black spot. Scape of antennæ rufous, infuscated above; the flagellum paler, infuscated above, especially towards the apex. Pro- and meso-notum with shallow, rather large punctures all over; the mesonotum darker in tint, thickly covered with a microscopic, white pile; the base of the post-scutellum black, obscurely crenulated; the median segment with a large, wide, deep, black depression in the middle; the depression becoming gradually, but not very greatly, nar-

rowed towards the apex; its centre itself has a furrow, and it is obscurely transversely striated. Pleuræ somewhat infuscated except at the base of the pro- and the middle of the meso- above; the mesonotum black. Legs pale rufo-testaceous, the tarsi paler; the hinder coxæ black beneath; the fore femora slightly, the four hinder more broadly, lined with black beneath. Wings hyaline; the apex with a blackish cloud extending from the second transverse cubital nervure to the apex; dark in the radial cellule, more obscure in the cubital; the nervures blackish; the stigma testaceous; darker along the upper border. Petiole with a distinct, narrow neck, from which it becomes gradually wider to the apex, which has a narrow, pale border; the second segment has the basal three-fourths or so obscure black, except on either side at the base; the third segment is blackish at the base; the fourth and fifth at the apex, laterally, the apical segments thickly covered with white hair. On the ventral side the apical four segments are black.

ANTHOPHILA.

COLLETIDÆ.

COLLETES DENTATA, *sp. nov.*

Long. 11—12 mm. ♀ et ♂.

Hab. Poona, Bombay (*Wroughton*).

The only Indian species of *Colletes* may be separated from the present as follows: —

Vertex with "a few fine punctures": the median segment at base longitudinally rugose, the apex with the sides smooth. *C. dudgeonii* Bng.

Vertex coarsely punctured, the median segment strongly reticulated; the sides of the apex transversely striated. *C. dentata.*

Clypeus apparently closely and rather strongly punctured, but the surface cannot be properly observed from the matting of the hairs; the front and vertex

coxæ, which has some large punctures; the rest coarsely punctured, at the apex running into reticulations. Legs ferruginous, the coxæ and the four hinder trochanters black; the hinder tarsi fuscous. Wings uniformly violaceous; the nervures and stigma black; at the top the second cubital cellule is only very slightly longer than the space bounded by the first recurrent and first transverse cubital nervures. Petiole slightly longer than the head and thorax united; the basal third almost impunctate; the rest strongly punctured; the part behind the tubercles distinctly narrowed; the tubercles indistinct; the second segment is closely and strongly punctured; the other smooth and shining; shortly beyond the middle of the petiole is an oval mark on either side; the apex is banded with yellow; in front of the middle and second segment is, on either side, an irregularly triangular mark; its apex is belted all round with yellow.

EUMENES ERYTHROPODA, *sp. nov.*

Niger, basi clypei, pronoto, scutellis maculis duobus, metanoto pedibusque rufis; alis violaceis. ♀.

Long. 15 mm.

Hab. Malacca.

Head coarsely punctured, the apex of the clypeus and the labrum smooth; the front and vertex thickly covered with long, fuscous hair; the clypeus and labrum with white depressed pubescence; black; the wedge-shaped space between the antennæ, almost the basal half of the clypeus, its apex and the labrum, rufous; the basal mark on the clypeus with two triangular expansions in its apex; the apex of the clypeus with a shallow, waved incision, the sides of which do not form teeth; the apex of the labrum rounded. The base of the mandibles broadly black; the rest rufous, slightly fringed with long, white hair; the palpi obscure testaceous. Antennæ black;

If Bingham's fig. 127 (*l.c.*, p. 408) represents the labium of *C. dudgeonii*, then that of the species here described differs from it in the labium being much wider than the mentum, and more widely and deeply divided at the apex. The same remark applies to Smith's figure (*Cat. Hym. Ins.*, i., pl. 1., f. 1). Bingham makes no mention of the fore wings having an appendicular cellule, nor is one indicated in his figure. In *C. dentata* the appendicular cellule is quite distinct, but open at the apex. The head and thorax are not very pubescent for a *Colletes*, but this may be through wear and tear. The wings vary in tint.

APIDÆ.

HALICTUS TORRIDUS, *sp. nov.*

Long. 5-6 mm.

Hab. Poona (*Wroughton*).

In Bingham's table (*l.c.*, p. 421) it comes in at "*C.* Enclosed space at base of median segment with longitudinal striæ. *b*¹. Abdomen impunctate," which contains two species;—*H. timidus*, which differs in having the abdomen and legs rufo-testaceous, and the Burmese *H. gutturosus*, which differs in having the eyes only very slightly convergent below; while here they are very distinctly convergent below; the pubescence on the head and thorax is "thin;" here it is dense and long.

Head closely and distinctly punctured in front; the clypeus thickly covered with depressed, white pubescence; the front, vertex, and hinder parts with the hair longer, more erect, and not quite so dense; eyes distinctly converging on the lower side, the space separating them there being about half the length of the vertex; they have a distinct curve near the top on the inner side. The face, below the antennæ in the centre, projects; the projection being wider at the apex, where it is clearly separated from the clypeus, which is as long as the space between its base and

the antennæ: its sides oblique, very slightly rounded towards the apex, which is transverse; the sides of the apex rounded: not so closely punctured as the front, but the punctures are as large. Antennæ as long as the head and thorax united: black: the scape with longish, white hair: the flagellum with a close down, which is especially thick on the lower side, giving it a fuscous appearance. Thorax shining, thickly covered with long, soft, white hair: the mesonotum and scutellum with shallow, not very large punctures; the apex of the median segment with an oblique slope: the enclosed space at the base finely rugose, the sides with some nearly straight, longitudinal striæ: the propleuræ almost impunctate; the mesopleuræ closely and rather strongly punctured; shining, sparsely covered with long, white, soft hair; the depression at its base wide, deep; the part above it bounded by narrow, oblique furrows, which converge slightly towards the top. Legs thickly pilose; the hair on the femora and tibiæ long and white, that on the tarsi very dense, pale golden. Wings clear hyaline; the nervures pale; the stigma darker at top and bottom; the second cubital cellule narrowed at the top; it is there half the length of the third at the top; the first transverse cubital nervure straight, oblique; the second and third curved; the first recurrent nervure is interstitial. Abdomen shining, impunctate; the apical segments sparsely covered with long, white hair. The first submedian nervure is interstitial.

ANDRENA EXAGENS Walker.

This bee, described by Walker, *Ann. Mag. Nat. Hist.*, 1860, from Ceylon, is omitted by Bingham.

SUDILA, *gen. nov.*

Head in ♀ elongate, narrower than the thorax; in ♂

broader than it, largely developed behind the eyes; the apex of the clypeus in ♂ produced into two stout teeth; the sides of the head, on the lower side behind, largely triangularly produced. Labial palpi 4-, maxillary 6-jointed; the first joint of maxillary half the length of the 2nd; the 2nd to 5th almost equal in length; the 6th a little longer. Mandibles in ♂ very large, curved, dilated towards the apex, which is itself prolonged into a long, stout tooth issuing from the middle of the dilated part; the middle with a long furrow in the centre. Labrum at top ending in a triangular point; the maxilla moderately large; the 2-5 joints almost equal in length, the 6th joint a little longer than the first. Body in ♀ and ♂ moderately, the legs densely, pilose; the claws with a stout tooth in the middle. Mesonotum with a narrow, but distinct, furrow down the sides, but not reaching the base or apex, and a less distinct, shallower furrow down the middle. Median segment without a distinct enclosed or striated space in the centre at the base. Prothorax transverse at the top, sharply raised there and at the sides. Pterostigma moderately large and elongate; the first cubital cellule somewhat longer than the second and third cellules united; the third cubital cellule narrow, not much more than half the length of the first; the first recurrent nervure almost interstitial; the second received close to the third transverse cubital nervure. Abdomen smooth and shining; the apical segments densely covered with long hair; the ventral segments densely fringed with long hair; the apical segments with a rima, as in *Halictus*.

The presence of a rima on the apical abdominal segment and the form of the alar neuration ally this genus to *Halictus*, nor is the structure of the trophi enough to separate it generically from that genus, while the ♀ again agrees with it in having an elongated face; the median segment in both sexes wants the enclosed space at the

base; so that the absence of the enclosed space on the median segment, and, more particularly, the presence of the longitudinal furrows on the mesonotum, which are not found, so far as I know, in *Halictus*, are the only points of distinction between them so far as regards the females. On the other hand the form of the head in the ♂ is so very different from what it is in *Halictus*, or indeed in any allied genus, that it cannot be included in it.

SUDILA BIDENTATA, *sp. nov.* (Pl. 4, f. 5, 5*a*.)

Nigra, nitida, sparse pallide hirta; alis hyalinis.

Long. fere 10 mm.

Hab. Ceylon (*Rothney*).

♂. Head shining, impunctate, sparsely covered with long, fuscous-black hair; a narrow, but distinct, furrow runs from the ocelli, which are bordered behind by a wider and deeper furrow. Mandibles piceous-red, except at the base and apex. Scape of antennæ sparsely covered with long black hairs; the base of the flagellum with short, stiff hairs; the rest of it bearing a pale down. Prothorax almost glabrous; its basal edge piceous; the mesonotum and scutella sparsely covered with long, black hairs. Median segment with a gradually rounded slope; its apex covered with long, white hairs. Mesopleuræ and mesosternum shining, impunctate, sparsely covered with long, white hairs. On the mesopleuræ, near the top, is a wide, oblique, deep furrow, which reaches near to the apex. Wings hyaline, the nervures and stigma black; the first transverse cubital nervure is oblique, straight; the second slightly, the thirdly distinctly, curved. The hair on the legs thick, longish, white on the femora, much thicker and darker coloured on the tibiæ and tarsi; the spurs and claws reddish. Abdomen very smooth and shining, the base glabrous, the apex thickly covered with long, stiff, fuscous-black hairs; the apical ventral segments thickly covered with long, fuscous hairs.

SUDILA FUSCIPENNIS, *sp. nov.*

Long. 10 mm. ♂.

Hab. Ceylon (*Rothney*).

This species differs markedly from the preceding in the form of the head; it is not so shining; the apex of the clypeus, instead of ending in the middle in two sharp teeth, has only a semicircular incision, the edges of which do not project; the lower part of the head at the sides has the projecting part not quite so lengthened, and is sharper pointed at the apex; the apex of the mandible is rounded in *S. bidentata*, here it is distinctly transverse and not so much narrowed; another marked distinction is found in the median segment; here its sides are bordered by a furrow, which is hardly visible in the other; the legs are distinctly fuscous, or rather piceous; the wings are distinctly smoky, being much darker coloured than in *S. bidentata;* the second cubital cellule is perceptibly shorter above and beneath than the third; the two being consequently together shorter than the first; the second transverse cubital nervure is straight, more oblique and more narrowed towards the first at the top.

If I had only *S. bidentata* to deal with, I should have inferred that the female described below was its female; but having two undoubted males of distinct species, I am unable to say to which of them it belongs, if indeed it may not pertain to a third unknown male. I therefore am compelled to treat it as a separate species.

SUDILA CEYLONICA, *sp. nov.* (Pl. 4, fig. 4.)

Nigra, nitida, sterno pleurisque longe albo-hirtis; alis hyalinis, stigmate fusco, nervis nigris. ♀.

Long. 10-11 mm.

Hab. Ceylon (*Rothney*).

Front and vertex sparsely covered with longish black hair; the front opaque, shagreened; a distinct, narrow

furrow runs down from the ocelli; the clypeus very shining, bearing some large, deep, widely separated punctures; its apex with two large, oval foveæ in the centre, and fringed with long, reddish-fulvous hair, as is also the labrum. The apex of the mandibles piceous, fringed at the base with a few long, fulvous hairs. Flagellum shining, sparsely covered with a few black hairs. Pronotum at the sides above triangular; the angles sharp; the propleuræ excavated, shining, impunctate, glabrous; the mesonotum shining, impunctate; thickly covered with fuscous hair, the hair on the sides to the tegulæ much thicker and paler; the middle towards the base with a shallow, not very distinct, furrow; and there is on either side, extending from in front of the tegulæ to the scutellum, a narrow, more distinctly defined furrow; scutellum and post-scutellum impunctate, thickly covered (especially the post-scutellum) with long, fuscous hair. The base of the mesopleuræ thickly covered with long, pale hair, the rest of it with the hair sparser. Median segment shagreened, the base without any enclosed or punctured space; sparsely haired; the apex thickly covered with long, white hair. Tegulæ very shining, impunctate. Wings hyaline; the nervures dark fuscous. Legs, especially the hinder, covered with long, white hair; the hair on the hinder tarsi very thick and long, and having a faint fulvous tinge. Abdomen shining, smooth; the base with a few scattered hairs; the apex thickly covered with long, fuscous hair; the ventral surface covered thickly with long, pale hair.

STEGANOMUS FULVIPENNIS, *sp. nov.*

Long. 7 mm.

Hab. Poona, Bombay (*Wroughton*).

The two new species here described may be separated

from *S. nodicornis* Sm., the only known Indian species of the genus, by the under-noted characters:—

Scape of the antennæ rufous, wings with the apex distinctly smoky; the basal area of the median segment only impunctate. *S. nodicornis.*

Scape of the antennæ black; wings not smoky at the apex; the base of the median segment impunctate. *S. fulvipennis* and *S. gracilis.*

Black; the antennæ, except at base and apex, the femora, tibiæ, and tarsi rufo-testaceous; wings hyaline, the stigmal region slightly smoky; the stigma testaceous, the nervures at the base pale testaceous, darker towards the apex of the wings.

♂. The scape of the antennæ black, bearing long, white hair; the second joint infuscated; the flagellum almost bare, finely punctured; the terminal joint black; the fourth joint is slightly longer than the third. Head black, the front, cheeks, and clypeus densely covered with pale fulvous hair; the front very closely punctured; the vertex at the sides of the ocelli with large, clearly separated punctures; the part behind the ocelli closely punctured, the punctures slightly larger and more distinctly separated than those in front of the ocelli, and much smaller than those on the sides. The pro- and meso-notum thickly covered with short, fulvous pubescence, this being also the case with the scutellum and base of post-scutellum; the latter is minutely and closely punctured. Median segment shining, almost bare; the base impunctate, the rest with moderately large, distinctly separated punctures; the apex with an indistinct, shallow furrow down the centre. Propleuræ impunctate, slightly shagreened; bare; mesopleuræ strongly punctured, densely covered with long, pale hair; the metapleuræ sparsely covered with long, pale fulvous hair and strongly punctured. Legs fulvous; the coxæ, trochanters, and base of four anterior femora black;

the femora on the lower side fringed with white hair; the tibiæ and tarsi thickly covered with white pubescence. The first recurrent nervure is received at a slightly less distance from the base than is the second from the apex of the cellule. Abdomen black, the ventral segments more or less ferruginous, the dorsal segments with broad belts of white, depressed pubescence at their bases, all the segments strongly and closely punctured, except at their extreme bases and apices.

The ♀ has the flagellum of the antennæ black above; the abdomen above much less strongly punctured; the legs thickly covered with long, fulvous hair; and the basal abdominal segments fringed with golden hair; the apical covered densely all over with pale, golden hair.

STEGANOMUS GRACILIS, *sp. nov.* (Pl. 4, f. 16.)

Long. 6 mm. ♂.

Hab. Mussooree (*Rothney*).

Agrees with *S. fulvipennis* in having the base and apex of the antennæ black and the apex of the wings not smoky; but is smaller and more slender, the third joint of the antennæ is not distinctly shorter than the fourth, the median segment is impunctate, the second recurrent nervure is received at a distinctly greater distance from the apex than is the first from the base of the cellule; and the abdominal segments are very much less strongly punctured.

Antennæ slender, testaceous, the apical two joints black; the scape broadly infuscated in the middle; punctured, sparsely covered with long, white hair. Front and oral region densely covered with pale fulvous pubescence; the vertex much more sparsely covered with longer hair, uniformly, but not very strongly, punctured. Mandibles broadly ferruginous in the middle. The base and apex of the mesonotum, the scutellum and

post-scutellum densely covered with pale, fulvous pubescence; the centre much more sparsely with shorter, darker pubescence, and closely and minutely punctured. Median segment very shining, the base impunctate, the rest with minute, scattered, shallow punctures. Propleuræ impunctate, glabrous; the basal three-fourths of the mesopleuræ covered thickly with pale fulvous hair; the apex and the metapleuræ sparsely covered with long, pale fulvous hair. Legs: the coxæ, trochanters, and the greater part of the femora, black; the tibiæ and tarsi rufo-testaceous; the femora sparsely, the tibiæ and tarsi very thickly covered with long, white hair, almost hiding the colour. Abdomen black, the ventral surface for the greater part ferruginous, the basal four segments closely punctured, fringed at the base with white hair; the apical segments impunctate, clothed with soft, white hair; the penultimate ventral segment is depressed in the middle, and with two large tubercles on either side. Wings hyaline, the stigma testaceous, the nervures blackish, the recurrent nervures are received about the same distance from the base and apex of the cellule.

NOMIA AUREOHIRTA, *sp. nov.* (Pl. 4, f. 7.)

Long. 10 mm. ♂.

Hab. Poona (*Wroughton*).

In Bingham's table (*l.c.*, p. 448), this species comes into *b. a.*[3] and into a new section *C*[4]:—Enclosed space at base of median segment transversely striated. In the form of the hinder femora in the ♂ it resembles *N. fervida*; but the form of the tibiæ is different; in *N. fervida* it is broadly dilated in the middle; in the present species there is no dilatation, but a gradual curve from the base to the apex; the under side of the femora also is straight to the keel, while in *N. fervida* the base is curved inwardly and the middle dilated slightly.

Head below the antennæ thickly covered with moderately long, golden pubescence; the front and the occiput thickly with longer, dark fulvous hair; the vertex rugosely punctured, sparsely covered with darker hair. Mandibles on the lower side with some long, fulvous hairs; black, piceous near the apex; the hinder orbits thickly covered with pale fulvous hair. Antennal scape lemon-yellow; thickly covered with long, fulvous hairs; the flagellum punctured, rufo-fulvous, darker above. The collar covered with depressed, yellow pubescence, behind fringed with long, dark fulvous hair; the mesonotum and scutellum thickly covered with a short, depressed, dark fulvous pile completely hiding their texture; the post-scutellum with a similar covering, but longer, and intersected with some fuscous hairs. The basal area on the median segment triangularly dilated in the middle at the apex; the middle at the apex with some short, transverse striæ; the sides obscurely striated. Mesopleuræ thickly covered with fulvous hair; more sparsely at the apex, perhaps through being rubbed; the metapleuræ covered with long, fulvous hair above. Legs, except the coxæ and trochanters, lemon-yellow; the femora and tibiæ at the base suffused with ferruginous; the fore tarsi fringed behind with long, pale fulvous hair; the hind femora semicircularly curved above, straight on the lower side, and with a small, oblique tooth near the apex; the tibiæ produced, at the apex in front, into a somewhat triangular projection which is gradually widened from the base of the tibiæ to the apex, the apex itself being rather acute. Wings with a fusco-fulvous tinge, darker at the apex; the stigma obscure fulvous; the second cubital celulle at the top about two-thirds of the length of the top of the third; the first recurrent nervure is received in the apical third of the cellule. The basal segment of the abdomen, broadly at the apex, and the second and third segments, in the

middle, thickly covered with fulvous hair; the apices of the first to fourth segments with a broad band of rich fulvous, depressed pubescence; the two apical segments thickly covered with long, pale fulvous hair. The ventral segments fringed at the apex with pale hair; the last deeply depressed in the middle, and having there a stout triangular projection.

NOMIA ERYTHROGASTER, *sp. nov.* (Pl. 4, f. 10.)

Long. 9-10 mm. ♂.

Hab. Poona (*Wroughton*).

Comes into Bingham's Section A (*l.c.*, p. 448). "*a*. Scutellum armed with two spines or teeth posteriorly," and "*b*¹. Abdomen beneath and posterior legs rufo-testaceous," which is now subdivided:—

Apex of post-scutellum distinctly bidentate; the second cubital cellule not one-half the length of the third on the top. Length, 7-8 mm. *N. westwoodi.*

Apex of post-scutellum not distinctly bidentate; the second cubital cellule more than one one-half the length of the third on top. Length, 10 mm. *N. erythrogaster.*

Head in front from near the ocelli thickly covered with white hair, that over the antennæ being much the longer; the vertex closely, but not deeply, punctured. Mandibles obscure ferruginous before the apex. The centre of the clypeus with a narrow keel; above this is a stouter keel reaching to the antennæ. Scape of antennæ covered above with long, white hair; the flagellum obscure brownish beneath. Mesonotum uniformly covered with shallow punctures; alutaceous; the base, sides, and apex thickly covered with white hair; the scutellum similarly punctured to the mesonotum, but with the punctures somewhat larger; the apex with the middle slightly depressed; post-scutellum thickly covered with white hair; the apex armed with two large, flat, slightly con-

verging teeth, which project backwards and are a little narrowed at the top. The basal area on the median segment long and narrow, bearing stout, longitudinal keels, widely separated in the middle, closer together at the sides. The sides of the median segment are strongly, but not closely, punctured, and covered with long, white hair. Pleuræ rugosely punctured, thickly covered with white hair. Wings hyaline, the costa and nervures fuscous; the second cubital cellule at the top half the length of the top of the third; the recurrent nervures are received in the apical third of the cellules. Legs thickly covered with white hair; the hind femora and tibiæ red, except the apex of the femora above, which is black; the hind femora dilated above; the apex of the hind tibiæ gradually dilated to the apex, the dilation a little longer than broad, transverse at the apex, with the sides rounded. Abdomen shining, impunctate, marked with four greenish blue belts; the ventral surface, except at the apex, rufous; the apex of the segments pale, thickly fringed with white hair.

NOMIA PURPUREO-LINEATA, *sp. nov.* (Pl. 4, f. 15.)*

Long. 10 mm. ♀.

Hab. Barrackpore (*Rothney*).

In Bingham's table (*l.c.*, p. 458), this species fits into "*b*, *b*¹. Thorax with griseous or white pubescence," and "*a*³. Clypeus with a medial vertical furrow," which now stands as follows:—

Clypeus coarsely punctured; abdominal segments 2-4 with blue or green transverse lines, wings hyaline. *N. iridescens* Sm.

Clypeus coarsely longitudinally striated; abdominal segments 1-5 with purple transverse lines; wings deeply fuscous except at extreme apex. *N. purpureo-lineata.*

* This group (that of *N. chalybeata* Sm.) forms the sub-genus *Paranomia* Friese.

Antennæ black; the flagellum obscure brownish beneath, bare; the scape with a few long, white hairs. Face elongate; keeled down the middle of the clypeus, closely longitudinally striated from the antennæ to the apex of the clypeus; the labrum smooth, shining, fringed at the apex with long, golden hair. Mandibles entirely black; the base with some long, white hairs. Front and vertex closely punctured; the sides, behind the antennæ, thickly covered with short, pale golden hair. Mesonotum alutaceous, closely punctured; an indistinct furrow down the sides; the scutellum punctured like the mesonotum, slightly depressed in the middle. Post-scutellum thickly covered with pale fulvous pubescence. The basal area on the median segment extending from side to side; sharply keeled at base and apex; irregularly longitudinally striolated; the segments from the area thickly covered with long, pale fulvous hair, and bearing large shallow punctures. Pleuræ shagreened; the mesopleuræ punctured, thickly covered with long, pale fulvous hair. Legs entirely black, except the claws, which are piceous; thickly covered with pale pubescence. Wings fuscous, tinged with fulvous; the costa and stigma black; the nervures fuscous; the second cubital cellule hardly narrower at top than at bottom; at top slightly more than one-half the length of the top of the third; the first recurrent nervure is received quite close to the transverse cubital. Abdomen shining, very minutely punctured; all the segments with a smooth belt of purple at their apices; the base of the petiole covered with longish, pale golden hair; the others at the base sparsely covered with long, black hair. Ventral segments obscure brownish; shining, the apices of the segments pale.

A very distinct species, easily separated by the violaceous bands on the abdomen and by the fuscous wings.

NOMIA LATISPINA, *sp. nov.* (Pl. 4, f. 11 ♀, 11*a*. ♂.)

Long. 7 mm.

Hab. Allahabad (*Rothney*).

Comes into a new section on foot of p. 448 (*l.c.*); C⁴. Enclosed space at base of abdominal segment smooth, neither punctured nor striated; apices of abdominal segments strongly punctured.

Head narrow, sharply oblique behind the eyes; the front and vertex with large, widely separated punctures; the front thickly, the vertex more thinly, covered with fulvous hair; the face and clypeus thickly with shorter, cream-coloured pubescence; the apex of the clypeus bare, rather strongly punctured; the mandibles shining, broadly rufous in the middle. Antennæ entirely black, except the flagellum on the under side, which is brownish; the scape bearing long, white hair. Thorax sharply transverse in front; the mesonotum thickly covered with depressed, scale-like, fulvous hair; the scutellum with only a few hairs; the post-scutellum covered thickly with long, pale fulvous hair. Mesonotum closely, rather strongly and uniformly punctured; the scutellum with the punctures, if anything, larger, and more widely separated. Median segment shining; the sides and apex with a few pale golden hairs; the basal area smooth, impunctate, triangular; the rest of the segment bearing large, deep, distinctly separated punctures. Meso- and meta-pleuræ thickly covered with pale fulvous hair. Legs black; the anterior tibiæ and base of tarsi rufous in front; the hinder tibial spine and metatarsus white; the hinder tibial process reaching to the apex of the metatarsus, very broad, not much narrowed towards the apex, which is rounded. The hinder tibiæ with a distinct, narrow keel down the middle on the outer side; the hinder femora largely dilated, becoming wider to near the apex, which is oblique on their under side; in the middle, near the apex, is a small

triangular tooth. Wings hyaline, the stigma and nervures black; the second cubital cellule small, shorter than broad; the first transverse cubital nervure straight; the second roundly curved, interstitial with the recurrent nervure. Abdomen shining, strongly punctured; the punctures large and deep on the basal three segments; the apex of the basal segment with long, fulvous hair; the base of the second, third and apical segments entirely covered with grey pubescence.

The form of the ♂ hind legs resembles that of *N. chalybeata* Sm. as figured by Smith (*Trans. Ent. Soc.*, 1875, pl. 11, f. 5).

NOMIA FULVOHIRTA, *sp. nov.* (Pl. 4, f. 9.)

Long. 12 mm. ♂.

Hab. Allahabad (*Rothney*).

Comes into Bingham's Section (*l.c.*) "*A. b.* Post-scutellum unarmed posteriorly. a^1. Thorax with more or less fulvous pubescence," consisting of *N. curvipes* Fab., the ♂ of which differs in having the hinder femora "rufo-piceous, with their apical-half yellow," here black, yellow at the apex, and the hinder tibiæ are broadly black at the base; *N. chalybeata* differs from it in having the femora not so much swollen nor toothed; *N. varipes* Cam. agrees with it closely; but may be separated by the rufous, not black, base of the hinder femora and by their having only one large tooth.

Head, except on the sides of the vertex, densely covered with long, fulvous hair; the vertex, except near the ocelli, bearing rather large, distinctly separated, punctures; the base of the mandibles yellow, the middle piceous, the apex black. The scape of antennæ yellow, except on the apex above; the flagellum fulvous, black above to near the apex. Thorax densely covered with long, fulvous hair; the basal area of the median segment

bearing stout, longitudinal keels. Legs yellow, thickly covered with fulvous hair; the coxæ, trochanters, the basal three-fourths of the four anterior femora and the basal half of the posterior femora, black; the hinder femora largely thickened; on the lower side near the apex are two stout teeth, separated by a semicircular space, the inner tooth being the larger; the teeth are black, as is also the under side of the femora. Hinder tibiæ greatly dilated towards the apex, ending there in a large curved, triangular tooth. Wings hyaline, with a slight fulvous tinge; the apex, from the radial cellule, infuscated; the costa, stigma and nervures fulvous; the second and third cubital cellules at the top are equal in length. The basal segment of the abdomen black; the apex greenish-yellow; strongly punctured; the base at the sides covered with short, the middle with long, fulvous hair; the second and third segments black, the apices greenish-yellow; the other segments greenish-yellow; the base of all the segments covered with fulvous pubescence; the apices glabrous; the ventral segments castaneous.

NOMIA VARIPES, *sp. nov.* (Pl. 4, f. 8.)

Long. 10 mm. ♂.

Hab. Allahabad (*Rothney*).

In Bingham's table (*l.c.*, p. 448), this species comes into "*A.* Abdomen with non-pubescent transverse fasciæ," and "*b.* a^1. Thorax with more or less fulvous pubescence," "a^2. Legs rufo-fulvous or ferruginous," presently represented by *N. chalybeata* Sm. and *N. curvipes* Fab., from either of which it is very different; from *N. chalybeata* by the abdomen not having blue-green fasciæ and by the spined femora; from *N. curvipes* by the femora having a large projecting tooth and not a semicircular incision, and by the apical projection on the hinder tibiæ being broader and blunter, not ending in a sharp curved tooth.

The form of the hinder femora and tibiæ most nearly resembles those of the Indian *N. combusta* and the African *N. calida*, but otherwise it is very distinct. The femora are formed pretty much as in *N. chrysopa*, but otherwise there is no resemblance.

Head black; front and vertex strongly punctured; sparsely covered with short, fuscous hair; a smooth furrow runs down from the ocelli; the face and clypeus densely covered with pale golden pubescence; the base of the clypeus yellow, the middle rufous, the apex black. The scape of the antennæ yellow, rather thickly covered with long, white hair; the flagellum rufous, slightly darker in the middle above. Pro- and meso-notum with the scutellum thickly covered with short, dark fulvous pubescence, and strongly and uniformly punctured; the median segment thickly covered with long, pale fulvous hair; the base with a row of stout, straight, short keels. Mesopleuræ thickly covered with pale fulvous pubescence; the metapleuræ at the base and apex fringed with long, pale fulvous hair. Wings hyaline; the apex distinctly smoky; the costa, stigma, and nervures fulvous; the second cubital cellule at the top equal in length to the top of the third; the first recurrent nervure is received near the apical fourth; the second in the apical third of the cellule. Legs yellow; the coxæ and trochanters black; the four anterior femora for the greater part above; and the basal two-thirds of the hinder femora ferruginous; the hinder femora large, broadly rounded above; the base, before the tooth, straight; the tooth oblique, directed towards the apex; the outer side of the apex of the hinder tibiæ curved; the inner projecting, in width not much less than half of the outer; its apex oblique, the inner side rounded; near the base of the hinder tibiæ on the posterior side is a large, black, oval mark, brownish on the outer edge. Abdomen shining, black; the apex of the basal segment covered

thickly with depressed, fulvous pubescence; the apices of the first and fourth segments broadly fulvous-yellow; the apical segments entirely of that colour; the apical segment thickly covered with long, golden hair; the ventral segments black.

NOMIA MAHRATTA, *sp. nov.*

Long. 8 mm. ♀.

Hab. Bombay (*Wroughton*).

In Bingham's table (*l.c.*, p. 449), this species comes into "*b*⁴. Thorax above with thin cinereous pubescence" which is now divided into:—

1. Area at base of median segment finely reticulate; the legs rufo-testaceous; the pubescence on the ventral segments cinereous. *N. aurata.*

2. Area at base of median segment finely longitudinally striated; only the hinder tibiæ and tarsi rufo-testaceous; the pubescence on the ventral segments dense, ferruginous. *N. mahratta.*

Head, from a little above the antennæ, thickly covered with white pubescence; the apex of the clypeus fringed with long, golden hair. The mandibles, before the middle, piceous; the front and vertex impunctate. Antennæ rather slender, black, the scape almost bare; the apical joint rufous. Thorax thickly covered with longish hair; fuscous in colour above, almost white on the sides; the mesonotum opaque, finely rugose, almost transversely striated; the scutellum shining, bearing shallow, scattered punctures, and sparsely covered with long, fuscous hair; the post-scutellum thickly covered with white pubescence. Median segment with an abrupt, oblique slope; opaque, finely and closely shagreened; the base with the area not clearly limited, and closely longitudinally striolated; the furrow on the apical half wide and deep at the base. Propleuræ shining, coarsely aciculated; the mesopleuræ at the tubercules thickly covered with white pubescence;

the metapleuræ covered with long, white hair. Legs black; the hinder tibiæ and tarsi rufous; the coxæ and femora covered with long, white hair; the tibiæ and tarsi more thickly covered with shorter hair; the hair on the hinder tibiæ being longer and thicker; the claws rufous. Wings hyaline, the apex slightly infuscated; the second cellule scarcely half the length of the top of the third; the costa and stigma black; the nervures fuscous; the second recurrent nervure is received the length of the second cubital cellule from the apex of the third cellule. Abdomen shining, impunctate; the base and sides of the basal segment covered with long, white hair; the sides and apices of the other segments fringed with white pubescence; the ventral segments thickly covered with dark rufous hair.

The antennæ in this species are more slender and the ventral surface of the abdomen more thickly pilose than usual, *e.g.*, than in *N. elliotti*.

NOMIA CHRYSOPA, *sp. nov.* (Pl. 4, f. 13.)

Long. 6 mm ♂.

Hab. Allahabad (*Rothney*).

In the Key (*l.c.*, p. 449) it forms a new group of the species with the abdominal fasciæ white; "*b*. Enclosed space at base of median segment, with stout, oblique keels," not punctured as in *N. oxybeloides*, nor obscurely transversely striated as in *N. rustica*.

Head black; from shortly above the base of the antennæ, thickly covered with golden pubescence, behind the eyes with longish, white pubescence; the vertex with longish, fuscous hair, longer and paler behind. Front and vertex closely and strongly punctured, except a small, smooth spot outside the hinder ocelli. Mandibles black; bearing at the base long, pale fulvous hair. The scape

yellow; the flagellum yellowish-ochraceous beneath; blackish above; the flagellum bare; the scape with long, pale hair. The edge of the pronotum on the top covered with a distinct line of dirty-yellow, depressed pubescence, in front of which is a narrow belt of long, pale hairs. Mesonotum closely and somewhat strongly punctured, opaque; sparsely covered with short, fuscous pubescence; the post-scutellum covered with longer, stiff, pale hair on the top. The "enclosed space" on the base of the median segment shining; distinctly margined behind: and having stout, slightly oblique, widely separated keels; the median segment with an oblique slope; rugose, obscurely reticulated at the top, and indistinctly keeled down the middle. Mesopleuræ thickly covered with long, pale fulvous hair. Legs bright lemon-yellow; the coxæ and trochanters black; the base of the femora broadly black, tinged with brown; a brownish mark on the outer and inner side of the hinder tibiæ; the hinder femora have, shortly beyond the middle, a large, oblique, triangular tooth; the hinder tibiæ gradually dilated to the apex, which ends on the inner side in a large, triangular tooth. Wings hyaline, slightly infuscated, especially towards the apex. Abdomen black, the apex of the basal three segments with a belt of white, depressed pubescence; the apical three covered entirely with similar pubescence; the first and second segments coarsely punctured; the third and fourth finely and closely punctured; the last rufous round the apex; the apices of the basal three segments covered with long, white hair, as is also the apical segment.

The form of the hind legs is not unlike those of *N. combusta*, with which it otherwise is closely related; but the shape of the femora serves to separate them; in *N. combusta* they are roundly curved before the tooth; in *N. chrysopa* they are perfectly straight, not curved in any way.

NOMIA MACULITARSIS, *sp. nov.* (Pl. 4, f. 12.)

Long. 8 mm. ♂.

Hab. Poona (*Wroughton*).

Agrees with *N. floralis* Sm. and *N. pilipes* Sm. in having the base of the abdomen red; only the females of these two species are known, but it can hardly be the ♂ of either of them. It comes nearest in those characters common to both sexes to *N. floralis*, from which it may be separated as follows:

> Median segment with a median vertical keel, the area at base densely punctured; the legs rufo-piceous. *N. floralis* Sm.
>
> Median segment without a median vertical keel, the basal area distinctly striolated; the legs black, the tarsi rufous. *N. maculitarsis.*

N. pilipes Sm. has the basal two and the basal two-thirds of the third abdominal segments pale-red, and the basal area of the median segment is "very coarsely punctured."

The head in front from shortly below the ocelli densely covered with fulvous hair; the front and vertex shining, impunctate. Mandibles black, striated; the striæ curved at the top. The propleuræ shining, impunctate, the apex only covered with long, white hair; the meso- and meta-pleuræ thickly covered with long, white hair. Wings hyaline, the costa, stigma, and nervures pale fuscous; the second cubital cellule at the top not half the length of the third at the top; the first recurrent nervure is received shortly beyond the middle of the cellule. Abdomen shining, the base and the sides covered with white hair; the basal segment entirely red, closely and finely punctured; the base and sides of the second rufous, the rest of it piceous; the apices of the second and following segments smooth, silvery white; the ventral surface entirely red. Legs black, the tarsi pale rufous, the hinder

infuscated towards the apex ; the hinder femora triangularly dilated above, below straight, except for a slight, blunt, somewhat triangular projection near the base ; the apex of the hinder tibiæ ends in a stout triangle, which behind is prolonged into a stout, roundly curved process, rounded at the end and piceous at the base of the apical tooth ; sparsely covered with long, pale fulvous hair ; the outer orbits bearing long, white hairs, which are longer and more numerous on the lower part. The scape and second joint of the antennæ entirely black ; the flagellum fulvo-brownish, blackish above ; the scape with a few fuscous hairs ; the flagellum bare. The pro- and part of meso-notum densely covered with long, fulvous hair ; the rest of the mesonotum with shorter hair ; in the middle of the mesonotum are two narrow furrows ; near the sides, opposite the tegulæ, is a slightly wider and deeper furrow ; the scutellum is sparsely covered with very long, pale hair ; the post-scutellum covered with white, woolly pubescence, and bearing also some long, white hairs ; the mesonotum is closely, but not very strongly, punctured ; the scutellum impunctate. The median segment is rounded at the base, semiperpendicular at the apex ; punctured, but not strongly ; the sides and apex covered with long, soft, white hair ; the basal area strongly obliquely distinctly margined on either side, the hinder trochanters are rufous ; the femora are sparsely covered with long, the tibiæ and tarsi thickly with short, white pubescence.

NOMIA (?) ALIENA, *sp. nov.* (Pl. 4, f. 14.)

Long. 7 mm. ♀.

Hab. Poona (*Wroughton*).

The undernoted species comes into Bingham's Section B. of *Nomia*, having the abdominal segments fringed with hair ; but it differs from all the species in the prothorax having in front of the tegulæ a curved, thin, horn-like,

semitransparent projection, extending equally on both sides of the tegulæ. Behind the eyes there is a sharp keel extending their entire length, and separated from them by a clear space.

Head as wide as the mesothorax; the front and vertex coarsely punctured, sparsely covered with short, fuscous hair; the centre below the antennæ shining, its middle almost impunctate; the base and apex with large, deep, widely separated punctures; the part next the eyes closely rugosely punctured, almost longitudinally striated. Clypeus with large, deep punctures, except near the eyes, where the punctures are smaller and closer. Labrum fringed with long, fulvous hair. Mandibles black, piceous at the apex; the base opaque, finely striated; with one large apical, and a smaller subapical tooth. Scape of antennæ fringed with longish pale hair above; the flagellum brownish beneath towards the apex. Pro- and meso-notum and scutellum shining, smooth; the meso-notum with three shallow furrows in front; the apex of the scutellum with a row of shallow, large, round punctures; the post-scutellum covered with white pubescence. Median segment with an oblique slope at the apex; without any basal area, but with a faint indication of two converging furrows. The mesopleuræ coarsely punctured at the base; the apex with a broad clearly defined space, broad at the top, gradually narrowed to the bottom, and bearing stout, longitudinal, distinctly separated keels. Metapleuræ shining, uniformly marked with shallow punctures and with a broad, shallow furrow at the base. Wings hyaline, the costa, stigma and nervures testaceous; the second cubital cellule is of nearly equal width, and scarcely one-half the length of the top of the third cellule; the first recurrent nervure is interstitial; the second received at the end of the second cellule, the transverse cubital nervure turning up sharply obliquely from it,

and not continued in a straight, or but slightly oblique, line from it as usual. In the hind wings, the nervures are not continued to the end of the wings. Legs densely covered with long, pale or pale fulvous hair; the hinder tarsi have the basal joint dilated above and compressed; the second joint is obliquely dilated above, both more so than usual.

NOMIA (?) INTERSTITIALIS, *sp. nov.*

Nigra, flagello antennarum rufo; alis hyalinis, nervis stigmateque nigris. ♂.

Long. 7·5 mm.

Hab. Allahabad (*Rothney*).

Scape of antennæ black; sparsely covered with long, white hair; the flagellum almost bare, infuscated above towards the apex. Face and clypeus sparsely covered with long, white hair. Clypeus finely punctured, finely longitudinally striated; the anterior ocelli with a curved furrow in front; behind them is a narrow ⌣-shaped one. Mandibles at the base covered sparsely with long, white hairs. Thorax above with short, fuscous pubescence; sparsely and shortly pilose; the hair on the scutellum longer; the basal area on the median segment large, closely and finely longitudinally striated, and bordered by a rather deep furrow, which is continued down the middle of the segment. Pleuræ densely covered with short pubescence. Wings short, reaching only to the fourth abdominal segment; the second cubital cellule small, shorter than broad; above one-half the length of the third; the first recurrent nervure is almost interstitial; but received nearer the base than the apex of the nervure; the second is received the length of the second cellule from the apex of the third. Legs black; the calcaria white; the coxæ thickly, the femora sparsely, covered with long, white hair; the tibiæ and tarsi very thickly with shorter, white hair;

the hair on the under side of the metatarsus rufous; the apex of the tarsi rufous. The femora and tibiæ are normal, not dilated, except that the hinder tibiæ on the inner side are triangularly produced, but not sharply, the apex being rounded. Abdomen shining, impunctate; the base of the segments belted with white, depressed pile; the second to fourth segment with wide transverse furrows near the base; the ventral segments smooth, shining; their apices fringed with short, white hair; the sides of the third and fourth with long, white hair; the penultimate segment broadly depressed in the middle, with a smaller, somewhat pear-shaped, depression on either side at the apex.

This is perhaps not a true *Vomia*. The trophi do not differ in form from those of that genus. The only point in which the legs agree with those of *Vomia* is in the projecting apex of the hinder tibiæ. It differs in the interstitial first recurrent nervure and in the shorter wings.

MEGACHILE NIGRICANS, *sp. nov.*

Nigra, capite thoraceque pallide hirtis; alis hyalinis. ♂

Long. 11 mm.

Hab. Trincomali, Ceylon (*Verbury*).

In Bingham's Key (*l.c.*, p. 471) it comes in "A. Abdomen black, with entirely black pubescence above," and "C. wings hyaline," which only contains the ♂ of *M. anthracina*, a very different species from *M. nigricans*, being much larger, the pubescence on the face bright fulvous, the fore legs more or less rufo-testaceous, the wings infuscated at the apex, the fore legs spined, &c.

Entirely black, the wings hyaline, the costa and nervures fuscous, darker at the base. Head below the ocelli thickly covered with long, pale, behind the ocelli more sparsely with longish, black, hair; front and vertex strongly punctured, except a smooth, shining space on the outer side of the hinder ocelli; the clypeus strongly

punctured; the labrum fringed with long, pale hair. Mandibles black, shining, the base covered with long, fuscous, intermixed with shorter, silvery hair; their apices shining, armed with one large, somewhat triangular, tooth at the apex; the base strongly punctured. Antennæ short, black, the apical half dull rufous on the under side; the scape with a few short hairs; the flagellum bare, shining. Pro- and meso-notum thickly covered with longish hair; longer and paler on the pronotum; closely rugose; the scutellum, if anything, more strongly rugose and with the hair longer; the median segment with a perpendicular slope, thickly covered with long, pale hair. Pleuræ thickly covered with long, black hair; the lower part of the mesopleuræ excavated, shining; the lower part of the metapleuræ smooth. Abdomen shining, pilose, the segments fringed with white hair; the ventral surface thickly covered with longish, stiff, blackish hair. Femora sparsely; the tibiæ and tarsi very thickly covered with long, black hair; the fore coxæ simple, not spined.

TETRALONIA.

Under this generic name Bingham describes two species—*T. duvancelii* Lep. = *elegans* Sm., and *T. himalayensis* Bing. In these two species the maxillary palpi are said to be 6-jointed. Whether this is an original observation, or merely copied from Smith (*Cat. Hym.*, ii., p. 297), who also gives six joints to the maxillary palpi of *Tetralonia*, I am unable to say. Apart from the difference in the number of palpal joints, my species agrees in the other generic characters with *Tetralonia* as given by Bingham. In both the species here described the maxillary palpi have only four joints, as have also the labial. Latreille, who first described *Tetralonia*, gives five as the number of joints in the maxillary palpi, this being likewise the number in Smith's genus *Xenoglossa*. Mr. W. H. Patton

(Generic Arrangement of the Bees allied to *Melissodes* and *Anthophora*. *Bull. U.S. Geol. Surv. Territ.*, v., p. 471) gives also five joints for *Tetralonia*, but it is not clear to me if he has himself examined the genus or gives a quotation from Latreille. *Melissodes* Latr. is described in full by Patton (*l.c.*, p. 472); it has, like our species, 4-jointed maxillary palpi, "the fourth joint often minute," which does not conform to our Indian species any more than does his description of the first joint of the labial palpi being twice the length of the second. In other respects our species do not quite fit into Patton's diagnosis. Further, they do not agree with each other in the form of the palpi. For those species with 6-jointed maxillary palpi, Patton established (*l.c.*, p. 473) the genus *Synhalonia*, representing *Macrocera* Lep., *Tetralonia* Sm., and *Melissodes* Cresson, *nec* Latr.; but it can hardly be regarded as generically identical with our species. Taschenberg (*Berl. Entom. Zeits.*, xxvii., p. 78) groups the genera under *Macrocera* (an inadmissible name, being preoccupied in *Diptera*); *Melissodes* Latr. with 4-jointed maxillary palpi; *Macrocera* sen. str. with them 5-jointed; *Xenoglossa* Sm. with them also 5-jointed; *Synhalonia* with them 6-jointed and *Ancyloscelis*, of which the palpal characters are not given, but which is treated by Smith (*Cat. Hym.*, ii., p. 365) as a doubtful synonym of *Tetrapedia* Klug, a very different genus from *Tetralonia*. As Mr. Rothney's ♀ differs in many respects from Mr. Wroughton's male and from the described genera, I give a generic description of it here, leaving it for further investigation to decide whether the points of difference in the palpal and other characters are of generic, sub-generic, or of mere specific importance.

♀. Antennæ shorter than the thorax; ocelli ∴. Mandibles without teeth. Tongue not elongate, if anything shorter than the palpi; the apex ending in a button; paraglossæ a little longer than the tongue; densely pilose;

the two basal palpal joints greatly enlarged and thickened; the basal slightly longer than the second ; the apical two joints of nearly equal length. The stipes longer and broader than the galea by about one-fourth ; the top on the inner side rounded inwardly and fringed with long, stout, stiff hairs ; the first and third joints of the palpi are nearly equal in length ; the fourth is slightly shorter ; the second is the longest. Wings very short, not reaching to the apex of the second abdominal segment ; the two recurrent nervures received quite close to the transverse cubital nervures. Fore wings with three cubital cellules ; the third at the top scarcely so long as the second ; at the bottom nearly twice its length. Legs densely pilose ; the hinder tibiæ and tarsi densely covered with long hair ; the calcaria simple, of nearly equal length ; the claws with a stout tooth near the base. Abdomen not densely pilose ; the apical segment with a large, smooth, glabrous area in the middle, somewhat triangular in shape, but with the apex rounded.

TETRALONIA BREVIPENNIS, *sp. nov.* (Pl. 4, f. 6, 6*a*, *b*.)

Nigra, flagello antennarum rufo; pedibus longe pallide pilosis; alis brevibus, costis, stigmate nervisque testaceis. ♀.

Long. 9 ; exp. at 6 mm.

Hab. Allahabad (*Rothney*).

Antennæ black ; the flagellum from its second joint rufous beneath ; bare ; the scape with a few short, black hairs. Head strongly punctured ; the clypeus more strongly than the front ; the sides of the vertex much more finely ; the occiput fringed with long, erect, white hair above ; the front and vertex with short, the sides of the clypeus with much longer, white hair. The apex of the clypeus distinctly margined, ferruginous. Mandibles rufous in the middle and fringed with long, fulvous hair on the lower side. Mesonotum and scutellum closely punc-

tured; the median segment at the apex with a steep, oblique slope; the base strongly and closely punctured; the apex with the sides less strongly punctured; the middle impunctate; the apex at the sides thickly covered with long, white hair. Legs thickly covered with long, pale fulvous hair; the floccus very long and thick; the metatarsus greatly enlarged, very thickly haired; the hair mixed with stiff spines. Wings reaching not much beyond the middle of the second abdominal segment; the second cubital cellule at top not much longer than the third at the top; the first recurrent nervure is received near the transverse cubital; the second is interstitial. The first tranverse basal is received before the basal, not joined to it. The basal segment of the abdomen is covered with long, white hair, almost bare in the middle at the apex, perhaps through being rubbed; the second, third and fourth covered with white, depressed pubescence; the fifth thickly with fulvous pubescence; the middle area on the last segment smooth, glabrous; the sides of the segment thickly covered with fulvous pubescence. The bases of the ventral segments covered with white pubescence; the apices of the three basal segments brownish; the hypopygium bare, sharply separated from the sides by a deep depression.

TETRALONIA PUNCTATA, *sp. nov.*

Long. 8-9 mm.

Hab. Poona (*Wroughton*).

In Bingham's key (*l.c.*, p. 520 *T. punctata* will come in as follows:—

Clypeus yellow.
Clypeus "very lightly punctured" *T. durancelii* Lep
Clypeus very strongly punctured all over. *T. punctata.*

Antennæ rufo-testaceous; bare, the basal joint black Head black; thickly covered with long, whitish hair,

except behind the ocelli; the clypeus and labrum lemon-yellow; the clypeus strongly and uniformly covered with large, shallow punctures, its apex almost transverse; the labrum punctured like the clypeus, but not quite so strongly, thickly fringed with long, white hair. Mandibles for the greater part ferruginous, black at the base, with a yellow mark in the centre. Thorax thickly covered all over with long, pale fulvous hair; the tegulæ yellow. Wings hyaline, the costa and stigma rufo-testaceous; the second and third cubital cellules almost equal in length at the top; the second at the bottom hardly one-half the length of the third. Legs thickly covered with pale hair; on the under side of the tarsi with rufous hair; the apical joints of the tarsi being rufous; the calcaria pale. Abdomen black; the basal segment thickly covered with long, pale hair; the second and third segments with a broad belt of depressed fulvous down on their base; the fourth and fifth covered entirely with pale, fulvous pile, the apical segments with the pubescence rufous, not pale fulvous; the ventral segments fringed with pale fulvous hair; the texture of the pygidium is hidden by the pubescence; the hypopygium is smooth, bare, the base black, the rest ferruginous.

The ligula is elongated, extending considerably beyond the palpi, is stout and densely haired; the paraglossæ are also hairy and are slightly longer than the palpi; the basal joint of the palpi is about one-half longer than the second; the apical two minute, the last shorter than the preceding. The second joint of the maxillary palpi is the longer, the rest subequal.

ANTHOPHORA CELLULARIS, *sp. nov.*

Long. 7-8 mm. ♂.

Hab. Poona (*Wroughton*).

In the table (*l.c.*, p. 525) this species comes in at

"*b*¹. Abdomen beneath black," which will now be subdivided into:—

Clypeus bimaculate; the second and third cubital cellules subequal. *A. confusa* Sm. and *A. fallax* Sm.

Clypeus immaculate; second cubital cellule not one-half the length of the third. *A. cellularis.*

Head black, the vertex and front closely, but not strongly, punctured; the cheeks impunctuate; the clypeus with some large, widely separated, punctures; the clypeus, a somewhat triangular mark above it, the sides from a little above the base of the antennæ, dilated in the middle to meet the upper mark, the labrum and the base of the mandibles, yellow; the mandibles piceous, intermixed with black. The front and vertex and the outer orbits thickly covered with long, griseous hair; the clypeus bearing a sparse pubescence; the labrum fringed with long, white hair. The scape of the antennæ yellow beneath; the flagellum brownish. The pro- and meso-notum thickly covered with short, dark griseous hair; the scutella with much longer white, the sides of the median segment and the pleuræ with long, white hair; the median segment closely punctured; the pleuræ are much more strongly punctured; the lower part of the metapleuræ obscurely longitudinally striated. The outer sides of the tibiæ and tarsi thickly covered with long, white hair; the metatarsus thickly covered on the inner side with long, bright rufous hair; the claws rufous. Wings hyaline; the stigma and nervures blackish; the second cubital cellule at top and bottom hardly one-half the length of the third; at the top it is half the length it is at the bottom; the first recurrent nervure is received near the middle of the cellule; the second distinctly in front of the third transverse cubital nervure, and not interstitial as it is with *A. fallax*, &c. Abdomen shining,

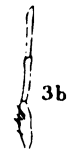
closely but not strongly punctured; the first to fifth segments banded with white pubescence, the last closely and strongly punctured above, the apex rufous; the hypopygium dark rufous, the middle carinate; the sides fringed with long, white hairs, the third to fifth ventral segments fringed with long, white hairs; the basal segments piceous.

EXPLANATION OF PLATE.

Fig. 1. *Mutilla indecora*, ♀.
„ 2. *Passaloecus reticulatus*, ♀.
„ 3. *Pterochilus fulvipennis*, ♂. 3*a*, labial; 3*b*, maxillary palpus.
„ 4. *Sudila ceylonica*, ♀.
„ 5. „ *bidentata*, ♂. head from the front; 5*a* from the side.
„ 6. *Tetralonia brevipennis*, ♀. 6*a*, maxillary; 6*b*, labium and palpi.
„ 7. Hind leg of ♂ *Nomia aureohirta.*
„ 8. „ ♂ „ *varipes.*
„ 9. „ ♂ „ *fulvohirta.*
„ 10. „ ♂ „ *erythrogaster.*
„ 11. „ ♀ „ *latispina*, and 11*a* ♂.
„ 12. „ ♂ „ *maculitarsis.*
„ 13. „ ♂ „ *chrysopa.*
„ 14. *Nomia alicna*, ♀.
„ 15. „ *purpureo-lineata*, ♀.
„ 16. *Steganomus gracilis.* ♂.

1

3a.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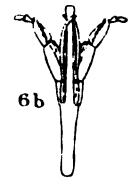
5a.

3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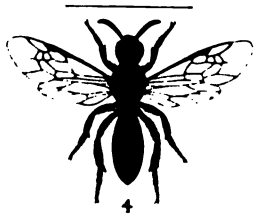
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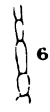
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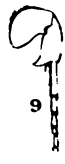
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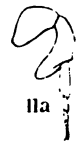
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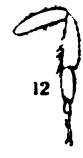
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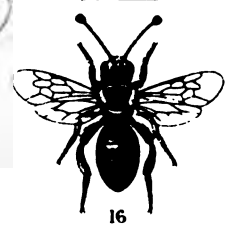
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HYMENOPTERA ORIENTALIA

Manchester Memoirs, Vol. xlii. (1898), *No.* 12.

THE WILDE LECTURE.

XII. "On the Physical Basis of Psychical Events."

By Professor MICHAEL FOSTER, Sec.R.S.

Delivered March 29th, 1898.

I very much fear that the title of my lecture (though I have found no better one) may have raised expectations which I cannot fulfil. We all know that what we subjectively recognise in ourselves and infer in others as psychical life, willing, feeling, thinking, is dependent on the integrity of that superficial layer of nervous material which we call the cortex of the cerebral hemispheres; by integrity I mean the well-being not only of the layer itself but of all its connections. We all know that physical changes in the cortex and changes in psychical life may be said, in a broad way, to accompany each other. I do not propose, in what I now have to say, to discuss what is sometimes spoken of as the connection of body and mind. I do not wish to make any attempt at throwing a bridge over the gap between the objective event and its subjective correlative. The task I have in hand is the simple and modest one of gathering together the fragments of knowledge which we at present possess as to what changes capable of objective appreciation, changes which we may accordingly speak of as physical, are going on in the cortex, while psychical developments are taking place, studying the parallelism between the one and the other, without daring to lay hold of the bonds which tie the two together.

September 13th, 1898.

And I am given to understand that I am to speak not so much to those who already know as to those who desire to learn.

I will take as a sort of text the physical events which lie at the bottom of that element of psychical life which we call a visual sensation. When 'light falls upon' the eye it produces in us, under ordinary circumstances, a psychical effect, a visual sensation. In order that the effect may be produced, the integrity of certain nervous structures is necessary. The retina within the eye is connected by the optic nerve and optic tract with the three nervous bodies called the corpus geniculatum, the corpus quadrigeminum and the pulvinar or hind part of the optic thalamus. Each of these three bodies is in turn connected by nervous strands with the superficial grey matter or cortex of the cerebral hemisphere in the occipital region. These nervous structures, the retina, the optic nerve and tract, the three bodies just spoken of, which I may call the intermediate bodies, and the occipital cortex constitute together a nervous mechanism, a visual mechanism, the integrity of which is essential to the development of visual sensations. Destruction of or interference with any part of this mechanism at once does away with or modifies the development of visual sensations, brings about blindness or defective sight; whereas on the other hand destruction of or interference with any other part of the nervous system does not necessarily and directly do away with or interfere with the mere development of visual sensations, though it may, in one way or another, indirectly affect vision. Obviously, when 'we see', the vibrations of the ether impinging on the retina give rise in this mechanism to events, the issue of which is a visual sensation. The visual sensation is a psychical thing. What are the physical changes, the changes which we can objectively lay hold

of, taking place in the mechanism during the development of the psychical effect?

The mechanism may be briefly described as a chain of linked units, the unit being the nerve cell, or, as it is sometimes called, the *neurone*. In order to make clear the characteristic features and properties of the neurone, I must for a while pass away from the special visual mechanism to the general nervous system.

A nerve cell consists, like the cell or unit of any other of the tissues of the body, of a *nucleus* lying in the midst of a mass of material spoken of as the *cell body*. In the typical nerve cell the cell body is prolonged into a number of processes, it may be many, it may be few, stretching away from the neighbourhood of the nucleus. The majority of these processes, all in fact but one, branching rapidly and extensively in ramifications or arborisations, end in fine points at no very great distance from the nucleus; these processes are called *dendrites* or *dendrons*. One process does not ramify in this way; it pursues an undivided course, it may be for a very long distance from the nucleus. Moreover, the material of which it is composed differs in microscopic appearance and in its reactions towards colouring and other chemical reagents from the material of the dendrites. Further, unlike, at least, the typical dendrite, it usually developes at a greater or less distance from the nucleus, around the material which is the prolongation of the substance of the cell body, a coating of a peculiar, largely fatty nature, spoken of as myelin or medulla. This undivided process is called the *axis-cylinder process*, or *neuraxon*, or, more briefly, *axon*; it has also been called the *neurite*. Though not ramifying like the typical dendrites, the axon not unfrequently, indeed usually, sends off at intervals, generally at right angles to itself, fine lateral twigs resembling itself, but more delicate, called *collaterals*, and, after pursuing its

unbranched course, it may be for a short, it may be for an exceedingly long distance, eventually ends in a terminal branching arborisation. Such are the main features of a typical nerve cell or neurone, a nucleated cell body giving off on the one hand branched dendrites, and on the other hand an undivided axon. There are, I need hardly say, variations from the type, but on these I need not now dwell.

The nerve cell or neurone is the unit of the nervous system in the sense that the whole system is made up of neurones, linked together in a special way, and surrounded by or embedded in a ground work, consisting of connective tissue carrying blood vessels and lymphatics, and of a special tissue called neuroglia, which ground work supports and nourishes the active real nervous tissue and at the same time serves to isolate each nervous element from its neighbours.

The mode of linkage deserves attention. In so many cases has it been observed that the terminals of an axon, either of the stem or of the collaterals, by means of branching or arborisation, more or less complex, impinge upon or surround or intertwine with the dendrites or some part of the cell not itself an axon, that this may be considered as the mode in which the cells are connected together. Axon does not link with axon, or dendrite with dendrite, the linkage is that of axon with dendrite. Further, in so many cases the connection has been found to be one not of fusion but of contact, there being a break of continuity at the linkage between the material of the axon and that of the dendrite, that this, too, has been assumed to be an essential feature of the linkage. This assumption, however, must be received with caution; indeed, it is maintained by some observers that in certain cases distinct fusion may be observed. But it may be argued that these cases are only apparent exceptions, the

difficulty of distinguishing between actual fusion and mere contact being in many situations exceedingly great, and the instances where the linkage is obviously one of contact only being exceedingly numerous. And, indeed, while admitting that the existence of a distinct mechanical gap is not an essential feature of the linkage, we may still assume that at each linkage there is between the linked units a line of demarcation, the material on the one side of which differs from that on the other.

Passing now to the question, what are the physical events, the events which we can lay hold of objectively, which take place during the life of a nerve cell, and which we may assume to be different when the nerve cell is at rest from what they are when the nerve cell is in a state of activity, we find that nearly all our exact knowledge is derived from observations made on nerve cells or parts of nerve cells prolonged outside the central nervous system as nerve fibres connecting that central nervous system, the brain or the spinal cord, with the various tissues of the body. These nerve fibres are on the one hand efferent fibres, the channels or instruments by which the central nervous system transmits influences to, or acts upon muscular and other tissues; and, on the other hand, afferent fibres, the channels or instruments by which various tissues, as the result of changes taking place in them, transmit influences to, or produce effects in the central nervous system.

The efferent nerve fibre is simply the prolonged axon of a nerve cell lying in the spinal cord or brain; the axon, for instance, of a cell whose nucleus and dendrites lie wholly within the spinal cord, leaves the spinal cord, and pursues its way, clothed with myelin or medulla and supported by connective tissue, until it reaches its destination, a muscular fibre for example, in which, after previous division, it ends in a terminal arborescence in connection

with the substance of the muscular fibre. The nature of an afferent nerve fibre is not so obvious. If we take a fibre of the auditory nerve, we find that it begins as a branched set of delicate filaments surrounding an auditory epithelial cell. These unite into a fibre which, becoming clothed with myelin, has in this and other respects at least a great resemblance to an axon. The fibre, pursuing its course, passes into a nerve cell of the so-called spiral ganglion, entering at one pole, while from the opposite pole of the cell proceeds a nerve fibre, an indubitable axon, which, making its way to a particular part of the brain, ends after the manner of an axon, by linkage with another nerve cell. The fibre which joins the nerve cell in the spiral ganglion to the brain is, as I just now said, indubitably an axon; the nature of the fibre which joins the auditory epithelial cell to the nerve cell of the spiral ganglion has been debated. It has been urged that it is an axon because it is clothed with myelin; for, in the case of the nerve cells lying within the central nervous system, the part which is clothed with myelin is always an axon; the dendrites are never so clothed. But all axons are not clothed with myelin; on the other hand, within the central nervous system, where the dendrites are devoid of a myelin coating, no instances are known of a dendrite being prolonged as a fibre to a considerable distance from the nucleus or main body of the cell to which it belongs, yet this is the case with this part of the auditory fibre, if we consider it as a dendrite of the nerve cell in the spiral ganglion. Moreover, at its beginning as an arborescence round the auditory epithelial cell, this fibre has the appearance of a dendrite; for that epithelial cell may be regarded as a potential nerve cell, without either axon or dendrites, as are all nerve cells at an early stage of their existence. Hence we may regard the fibre, the nature of which we are discussing, as the dendritic moiety

of a nerve cell linking the auditory epithelial cell with a nerve cell in the auditory territory of the brain, though its dendritic nature is obscured save at its very beginning.

Analogous to the auditory afferent fibre is the common sensory afferent fibre, connecting the skin with the spinal cord or brain. This, too, begins as a dendritic branching in connection with the epithelial cells of the epidermis, pursues its way as a myelinated axon-like nerve fibre belonging to a nerve cell in the posterior ganglion of a spinal nerve (or its analogue in the case of the cranial nerves), which nerve cell sends forth an indubitable axon to end by linkage with some cell or cells within the central nervous system. A special feature, however, of these ordinary sensory fibres is that, in animals above fishes, the nucleus with the surrounding part of the cell body does not lie in the course of the fibre, the fibre entering at one pole and issuing at the other, but is drawn away all together from the fibre with which it is connected after the fashion of a T-piece; hence the main cell body seems to give rise to one fibre which divides into two, each pursuing a different course. But this special disposition of the nucleus is of very secondary importance.

Of more importance is the consideration that, at least in ordinary circumstances, while an efferent fibre seems to be engaged in transmitting influences along itself from a cell in the central nervous system to a muscular fibre or other peripheral tissue, an afferent fibre is engaged in transmitting influences from the skin or other peripheral tissue to the central nervous system. Hence, if we adopt the view that in the afferent fibre the part peripheral to the nucleus is of the nature of a dendrite, in spite of its being clothed with myelin along by far the greater part of its course, we may say that in both cases the influences are transmitted along the axon away from the nucleus or its neighbourhood, and along the dendrite towards the

nucleus, or at all events towards the beginning of the axon.

It is in our power to excite or stimulate by artificial means, by electric currents or by other forms of stimulus, these nerve fibres lying outside the central nervous system. And we find invariably that, whatever part of the course of a fibre we may artificially stimulate, we produce by means of afferent fibres effects in the central nervous system only, none in the periphery, and by means of the efferent fibres, effects in the periphery only, none in the central nervous system. The former acts apparently in a centripetal manner only, the latter in a centrifugal manner only.

I may now return to the question—What events can be ascertained to take place in a nerve fibre when it is stimulated?

When we study the events taking place in other tissues, in muscular fibres, gland cells, and the like, we find clear evidence that the phase of activity, the contraction of a muscular fibre, the act of secretion in a gland cell, is accompanied by chemical changes, by electric changes, and by the setting free of energy in the form of heat. In the gland, where chemical change is the goal of activity, the development of heat is economised or even minimised; in the muscle, where energy is in like manner the goal, the development of heat is larger, and is utilised for the good of the economy. When, on the other hand, a nerve fibre is stimulated, the most careful examination fails to detect either chemical change or the setting free of heat. The phase of activity of a nerve fibre is marked by one objective token and by one only, an electric change giving rise to an electric current known as the current of action. This electric change is witnessed during the activity of a nerve fibre in all cases, not only when the nerve is excited artificially, but also when it is the instrument of natural nervous events, of sensation, and of movement. Moreover,

as has been especially shewn by the researches of Waller, this current of action may be taken not only as the token, but also as an exact measure of vital activity; the sweep of the current rises or falls as the power of the nerve fibre waxes or wanes.

Taking this electric change as the sign and, indeed, as the measure of the events in a nerve fibre which constitute its phase of activity, and which we speak of as a "nervous impulse," we are able to estimate the features of nervous impulses, the rate at which they travel along a nerve fibre, the length of nerve fibre occupied by a nervous impulse as it sweeps like a wave along its course, and such rises or falls of its amplitude as may from time to time occur.

In this way we find no essential differences between a nervous impulse of natural or of artificial origin. When a nerve fibre is stimulated at any point of its course by an electric current or other artificial stimulus, or when it is thrown into action in a natural way, and is the instrument of sensations or of voluntary or other movements, the nervous impulse, as shewn by the electric change, possesses the same essential features, such difference as occurs being one of energy only. Further, we have reason, by the same token, to think that when a nervous impulse sweeps along even a great length of fibre, it does not materially change otherwise than perhaps by somewhat diminishing as it passes along.

Further, while it is a prominent characteristic of the tissues of the living body in general that activity, whether natural or artificial, when carried beyond certain narrow limits, leads to fatigue and ultimately to exhaustion, careful observations shew that to the nerve fibre under artificial stimulation exhaustion is unknown. Every complete nervous mechanism, involving more than the mere nerve fibre, is not only subject to fatigue, but is perhaps more readily subject than are even other tissues, as is notably

seen in the nervous mechanisms of sensation; and fatigue is more readily induced by artificial than by natural stimulation; but when we come to deal with the nerve fibre by itself (and in such cases the stimulation is almost necessarily artificial), and with the mere transmission of nervous impulses, apart from their terminal effects, we find that exhaustion cannot be induced by even the most powerful and prolonged excitation.

Two views may be taken as to the nature of this untiredness of the nerve fibre. It has been supposed on the one hand that the molecular changes which constitute the nervous impulse are of a nature wholly unlike the changes which in all other living tissues lie at the bottom of activity, that the changes in the nerve fibre involve no consumption of energy. On the other hand it may be urged that in the nerve fibre the nutritive changes are so admirably balanced, and respond to the demands made upon them with such exquisitely arranged swiftness, that what is lost by action (and that we may assume to be little, for the change of electric potential, even though conspicuous, is exceedingly small) is at once, without loss of time, made good. So far as I know, we do not possess any crucial test to decide between these two views; we have no exact proof in one direction or the other; but, on the whole, the latter view may, from many considerations, be taken as the more probable one.

If, for instance, we pass from the nerve fibre itself, which, as we have seen, is a part only of the nerve unit to the whole unit, to the nerve cell or neurone in its entirety, we find that the nutrition of this is exquisitely cared for. In all living units, in all living cells, the nucleus presides, governs, and determines the nutrition of the unit. If a simple unicellular organism be divided into two parts, so that the nucleus remains in one only of the two, the nucleusless fragment, even though it be the larger one,

may live for a brief period on its accumulated vital capital, but when this is expended perishes; it cannot live of itself, it cannot grow, it cannot reproduce itself. The fragment containing the nucleus, however, can live of itself, can grow, can reproduce itself. The nerve cell obeys the same law; the nucleus governs the nutrition of the whole unit, not only of the ordinary dendrites and of the cell body immediately surrounding itself, but of the whole axon, however long that be. The efferent nerve fibre is dependent for its nutrition on the nucleus of the cell in the spinal cord or brain, of which it is a prolonged axon. The afferent nerve fibre is dependent for its nutrition on the nucleus of the cell in the posterior spinal ganglion (or analogous structure), of which it is, as we have seen, either a prolonged and specialized dendrite or a portion of an axon. If either fibre be cut off from its nucleus, it undergoes degenerative changes, it dies, never to become alive again, though it may be, and that even exactly, replaced by a growth of the stump left behind still in connection with the nucleus.

This nutrition of the long-extended nerve fibre, be it called an axon or dendrite, is in many respects a complex and peculiar business. The fibre along its whole length is supplied with blood vessels and bathed in lymph; from this lymph it takes up material, far away from the nucleus, and by this lymph it is directly nourished; for if this local nutriment be interfered with, it, the fibre suffers, however intact may remain its ties with its nucleus. Yet it cannot avail itself of this nourishment unless those ties be intact. Something is continually going on between the nucleus and far-distant parts of the axon which determines the absorption and utilisation of the material lying to hand around those distant parts.

Further, in all living units we are able, by careful observation, to catch sight of visible tokens of the work of

nutrition. Scattered amidst the living, fully-elaborated substance of the cell, in which substance, and in which substance alone, often apparently structureless, the living powers seem to reside, we are able to detect granules and heaps of granules of varying refractive power and varying reaction towards colouring and other chemical reagents. These we have reason to think are either food material about to undergo further elaboration, or waste material about to be further transformed and ejected. These appreciable granules whose changes we can see, and many other things which we cannot see and never shall see, are tokens of the laboratory; they are signs of the nutritive work which is going on.

Now, in the nerve unit, the neurone, while we have like abundant evidence, like conspicuous laboratory tokens of nutritive labours in that part of the cell which surrounds the nucleus, in what has been called the perikaryon, as well as in the ordinary dendrites, all such tokens are strikingly scanty if not entirely absent in the axon which constitutes an efferent fibre, or the modified dendrite which constitutes an afferent fibre. Indeed, while staining chromophile granules, or groups of granules, small or large, supply conspicuous features of the perikaryon of every nerve cell as well as of the dendrites to even a long distance from the nucleus, the axon, the axis cylinder process of the cell is distinguished almost as soon as it separates off from the perikaryon (or from the dendrite in the cases where it seems to start from a dendrite) by the paucity or even absence of such granules. In the perikaryon and in the greater part of the dendrite, the elaborated, active, truly nervous material is crowded and elbowed by the grosser material out of which it is making itself, in the axon as little as possible of this grosser material is left, the greater part of the axon is sifted, elaborated matter clogged as little as possible by coarser lower stuff.

It is only by means of this coarser visible material that we get ocular evidences of the work of nutrition. Hence it is in the perikaryon and the clustering dendrites, not in the long drawn-out axon that we get visible indications of how the nutrition of the cell is influenced by circumstances, by rest or activity, by disease or by toxic agents. But it is the evidence only which is thus limited, not the effect. The work of the laboratory of the perikaryon is carried on for the good not of itself only, but of the whole unit, for the good not of the part close round the nucleus only, but of the whole stretch of axon or dendrite down to its furthest terminal twig. Our knowledge of the intimate nature of this work of nutrition, of the building up and clearing away of the exquisitely organized, that is, molecularly organized, material which alone does "nervous work" is of the scantiest; but it is at least obvious that the processes of this nutrition are complex. While in the nutrition of a distant portion of the axon, part of the work is being done on the spot, part is being done in some way or other by the perikaryon. More than this we cannot at present say.

Moreover, not only is the axon dependent on the perikaryon, but the latter also is dependent on the former. When an axon is cut across, the portion in connection with the perikaryon and nucleus does not degenerate and perish like the peripheral portion. Nevertheless, the perikaryon, indeed, the whole remaining nerve cell, does undergo visible structural changes if it be deprived of the nerve fibre which springs from it. This takes place not only when an afferent fibre is cut away, in which case the changes might be supposed to result from inaction, from the absence of customary impulses passing towards the nucleus along the fibre, but also when an efferent fibre is cut away, in which case the cell within the central nervous system is still subject to the influences which ordinarily

play upon it, though it is unable to carry out the behests of those influences.

Putting these various things together we are led to the conclusion that quite apart from the grosser changes which we call a nervous impulse, and which are signalled by an electric change, by the current of action, there must be passing to and fro between the several parts of the neurone, between perikaryon and the farthest point of axon or of dendrite, influences, actions, currents, call them what you will, which are signalled by no appreciable electric change, and of which we have at present no direct signs, no indications beyond the phenomena on which I have just dwelt.

The perikaryon seems to be the chief laboratory. It is here that we find evidence of obvious chemical changes, and especially of changes connected with activity. But I venture to think it would be a mistake to infer, as some seem inclined to do, that these metabolic events of the perikaryon, because they make themselves visible there and there only, produce their effects there only. One at times meets with statements which seem to assume that the perikaryon, that part of the nerve unit which is often called the nerve cell as distinguished from the other parts which are called nerve fibres, is alone the seat of the setting free of energy. The facts, however, of which I have been speaking, point to the conclusion that the good of what is done in the perikaryon is, in some way or other, shared by the whole unit. It may be beyond our present knowledge to frame any hypothesis as to how the chemical labours of the perikaryon are made available for the distant parts of axon. As I have just said, we have evidence that the nucleus is in some way or other in touch with every part of the axon along its whole length, but we are at present in ignorance as to the exact nature of that touch ; we do not

know how it is that the chemical change in the perikaryon influences that chemical change at the periphery of the axon which is the basis of the local nutrition of that structure. Nevertheless it seems clear that the perikaryon does work for the good of the whole unit and not for the good of itself alone. This is incidentally shewn in the case of the spinal ganglion of the lower vertebrates. In these the cells of the ganglion are bipolar cells. The incoming axon or axon-like dendrite reaching one pole of the perikaryon spreads out, losing itself among it, and then is gathered up at the opposite pole to issue as a veritable axon. In such a case the afferent fibre passes through the substance of the perikaryon, and we may assume that it passes along definite paths, along strands of axon-like material imbedded in the perikaryonic laboratory mass. Yet we have no evidence that this perikaryonic mass in any way influences the impulses which sweep through the ganglion on their way from the skin to the spinal cord. The perikaryonic mass influences the whole stretch of axonic material which forms the axis cylinder of the nerve fibre on this side and that side of the ganglion; but it has no direct and special local effect on the threads of axonic material which traverse itself between the two poles of the cell. It works not for that part of the unit alone but for the whole unit along its whole length.

This, then, is one fundamental feature of the neurone, that it is essentially a unit, all the various parts being strikingly integrated into a whole, so that whatever affects a part, affects not the part alone but the whole unit.

A second fundamental feature of the nervous system, to which I now wish to call your attention, is one which I may introduce under the term of "the differentiation of units." The whole nervous system is, as we have seen, a linkage of units, the linkage being not by real fusion but by contact, the break of continuity between link and link

being, at least in the majority of cases, obvious and distinct.

The nerve fibres which compose the nerves are, as we have seen, parts of units of two different functions, parts of afferent or sensory units and parts of efferent or motor units. Now, when we study nerve fibres by the help of artificial stimulation, and take the current of action as the token of the phase of nervous activity of the nervous impulse, we can find no differentia between the sensory and motor unit. In both, the nervous impulse travels with equal facility in either direction, and with the same features. We can with ease drive a nervous impulse backwards towards the periphery along an afferent fibre, and forwards towards the spinal cord along an efferent. We can, in certain cases, do the same thing along fibres running within the central nervous system, and the nervous impulse thus propagated in what appears to be an inverse direction, may manifest itself by other effects than the mere current of action.

Nevertheless, when we deal not with parts of units but with units linked together, the nervous impulses, nervous changes, nervous influences, call them what you will, pass across the linkages in one direction only, and that may be broadly defined as the direction from the sensory or afferent unit to the motor or efferent unit. Not only natural but artificial impulses readily pass from the afferent axon to the motor units, with which that axon is linked. They do this irrespective of the direction in which they are passing along the axon. The afferent axons of the cells in posterior spinal ganglia pursue a long course within the spinal cord, constituting definite strands. As each axon passes along, it gives off collaterals, which, in many cases, form linkages with motor units. Natural impulses flowing up the axon from the ganglion, and coming ultimately from the periphery, may pass into a

collateral, and if so, may, under favourable circumstances, excite to motor activity the motor unit with which the collateral is linked So also, artificial impulses passing down the same axon from higher parts of the spinal cord towards the ganglion and periphery, and flowing into the same collaterals, may produce just the same motor effects. Any impulse, however produced and in whatever direction flowing, can pass from unit to unit across the linkages in the direction from afferent to efferent. But in no single case has it been found possible to drive an impulse across a linkage in the contrary direction, from the efferent to the afferent unit; or, speaking more generally, from the efferent unit to any of the other units with which it is linked. This general feature is known under the name of "Bell's Law." Stimulate a motor nerve fibre as much as you please, you will obtain abundant evidence that the nervous impulses, as indicated by currents of action, are flowing inwards towards the cell from which the fibre arises, towards the perikaryon of which the fibre is the axon. You may be sure that the impulses reach the nerve cell, but there they stop. You will not find the slightest evidence of any other units being in any way influenced. So far, at least, as gross nervous impulses are concerned, the linkage is a valve admitting passage in one direction only.

Further, at the linkage there is a change in the nature and character of the impulse. As I have already said, all the evidence goes to shew that an impulse as it travels along a nerve fibre undergoes no material change. So long as it merely passes along an axon, so long as it is confined to a unit, it may perhaps be slightly diminished in intensity, but otherwise is not changed. When, however, it leaps from one unit to another, a change does take place. This is seen in the relatively simple action of unit upon unit, commonly called a reflex action. An

impulse, or a group or series of impulses travelling along a sensory fibre, along the axon of a sensory afferent unit, impinges on the body or dendrites of one or of more than one motor unit; forthwith there issue along the axons of these motor units, impulses which are wholly incommensurate with the exciting impulse. That exciting impulse or that series of exciting impulses may be exceedingly feeble and yet may, under suitable circumstances affecting the motor unit, give rise not only to numerous but to most powerful impulses in the motor unit. A reflex action is not, as the term would seem to imply, the mere reflection of a centripetal afferent sensory impulse into a centrifugal efferent motor impulse. The issuing motor impulses of a reflex action are the outcome of the special activity of the motor unit. The characters of that activity are, in the main, determined by the features, properties, circumstances of the motor unit itself; the afferent impulses do little more than start the activity of the motor unit, they are to be regarded as of the nature of a stimulus which awakes the irritability of the motor unit, somewhat as they themselves were started by an external stimulus applied to a sensory unit. The manifestations of the motor unit may, it is true, be not only started, but also in a measure determined by the characters of the sensory impulses, a strong, sensory impulse producing effects different from those of a weak one, and so on; but the real features of the motor act are determined by the individuality of the motor unit.

Moreover, the effect of the advent of afferent impulses at the doors of a motor unit may be, not as in an ordinary reflex act, the development of motor impulses, and so of movement, but the very reverse, the arrest of movement; the effect may be inhibitory. And this, we have reason to think, may take place without our being able to detect any differences in the nature of the afferent impulses

themselves, in the two cases of movement and of inhibition. Whether an afferent impulse stirs up a motor unit to activity or checks an activity already in play, is determined by the relations of the afferent impulse to the condition and circumstances of the motor unit, not by any essential differences in the nature of the afferent impulse in the two cases.

This is true, at least, so long as we judge of the nature of a nervous impulse by what we have seen to be the only objective token in our possession, the electric current of action.

We must not, however, trust too much to these currents of action. We certainly are not justified in assuming that the only phases of a nerve unit are the two phases, the one of rest, in which no currents of action are developed, the one of activity, signalled by a current of action. We have increasing evidence of cases in which a motor unit, quite apart from its being thrown into an activity manifested as movement, exerts on the peripheral, muscular or other elements with which it is connected, a more gentle continued influence, commonly spoken of as *tonic action*. Now this tonic action, so far as we know, is not accompanied by any such electric change as that which marks the grosser ordinary nervous impulse. It is the effect of gentler, subtler influences passing along the axon, influences more nearly allied, of which we spoke a little while back as concerned in the nutrition of the unit.

Such a tonic influence exerted by a unit may be modified positively or negatively, may be increased, augmented, or may be diminished, inhibited, by various influences; and in many cases these influences are of the nature of gross nervous impulses brought to bear on the unit by other afferent units. In such cases there can be no question of a mere reflection. The individuality of the efferent unit is stamped on all its work.

These, then, are the fundamental principles of the action of the nervous system on which I wish to insist as a basis for any further considerations. The nervous system is a congeries of chains of units, linked together in definite ways. Each unit possesses individual powers and characters, in part born with it, the outcome of events in past times, in part developed during its own growth, as determined by its own individual circumstances. The several units act the one on the other, and the manifestations of nervous life are brought out by the integration of the differentiated activities of the individual units. Each unit is essentially a unit acting as a whole, with all its parts accordant. Any change of activity which occurs takes place not within the unit while the phase of activity is sweeping along the unit, but at the linkage where unit joins on to unit. Further, the action of unit on unit is varied; it may be the inducement of that grosser kind of activity, marked by an electric current of action which we call a nervous impulse, it may be something else; it may be one of the many things of which we possess no clear objective token, such as is supplied by the electric change, and about which, therefore, we are as yet greatly in the dark.

Let me now turn to apply these general principles to the problem of visual sensations.

Put in its simplest form, what takes place in the nervous mechanism of vision is somewhat as follows.

Light falling on a cone (or rod, but for simplicity's sake we may omit the double character of the initial elements) sets up in this changes which are propagated along the cone fibres. The cone and cone fibre are the respective parts of an epithelial nervous unit or neurone, the cone fibre being the axon. By the terminals of the axonic cone fibre this first unit is linked on to a second unit, the

"bipolar cell." (I am purposely omitting various complications existing in the retina, as not bearing directly on my theme.) This, again, by the terminals of its axon is linked on to a "ganglionic cell," whose axon is a fibre first of the optic nerve and then of the optic tract. This constitutes the first or retinal portion of the mechanism.

Now, we can easily obtain evidence that when the retina is stimulated, either naturally by light or artificially by other means, currents of action are developed in the optic fibres. We may take these currents as the objective tokens of what we have called nervous impulses passing along those fibres. Consequent upon the development of these nervous impulses in the optic fibres, visual sensations are developed if the remaining cerebral portion of the mechanism be intact; the nervous impulses in the optic fibres give rise in the cerebral mechanism to visual sensations.

So far as the objective token of the electric current is concerned, we can find no difference between these optic impulses, these nervous impulses along the optic fibres, and the nervous impulses of an ordinary nerve.

And yet they are different. If we stimulate artificially an ordinary nerve fibre at any part of its course, we can produce effects which, within certain limits, are identical with the effects of natural stimulation. If we artificially stimulate a motor nerve, we can almost if not quite completely reproduce natural effects, movement and the like. If we stimulate a sensory nerve, we can at least reproduce the natural effect of pain, and many other natural effects. If, on the other hand, we stimulate artificially the optic nerve at any part of its course, we do not according to the most trustworthy observations, though all observers are not agreed, give rise to visual sensations; so far as can be ascertained we do not produce any psychical effect whatever. If the retina be stimulated, whether the stimulus

be the natural one of light or an artificial one, such as pressure, an electric current, a chemical agent and the like, we do get psychical effects, we do produce visual sensations, and the visual sensations resulting from an artificial stimulation are, in their essential features, identical with those resulting from natural stimulation. But if the optic fibres be stimulated directly, no psychical effect is produced, neither sensations of light, nor sensations of pain, nor sensations of any kind. We infer that the natural nervous impulses which sweep along the optic fibres when the retina is stimulated are of a different nature from those which sweep along it when it is directly stimulated by artificial means, though both give the same token of currents of action. The former are differentiated impulses, and it is differentiated impulses alone which can so act upon the central cerebral portion of the visual mechanism as to give rise to psychical effects.

I may here remark in passing that a similar arrangement probably obtains in regard to the psychical effects of sensation, of touch proper, and of temperature, as developed in ordinary sensory cutaneous nerves; artificial stimulation will produce pain, but not the specific tactile or temperature sensation. The case, however, is not so clear here as it appears to be in vision, and I only mention it incidentally.

To return to visual matters. The optic impulses, as they travel along the optic nerve, have already become differentiated. Though we possess no experimental evidence on the matter, we may infer that the differentiation is effected by successive steps at the several linkages. We do not know the details of the changes which take place in the cone cell, in the primary visual unit when light falls upon it; somehow or other the disturbances of the ether give rise to material changes, changes which we may probably characterise as nervous, travelling along

the cone fibre. At the linkage of the cone fibre with the bipolar cell there takes place, we may infer, the first differentiation. We may assume that whatever be the exact nature of the changes which take place in the bipolar cell, these are different from those taking place in the cone cell. At the linkage of the bipolar cell with the ganglionic cell, a second differentiation takes place. Through the two linkages, in accordance with the general principles on which, a little while back, I dwelt so long, the simpler events started in the cone cell give rise to the subtler events which travel onwards from the ganglion cell along its axon, the optic fibre.

The differentiation thus begun in the retinal portion of the mechanism is continued in the central cerebral portion. The optic fibre, the axon of the ganglion cell, runs a course the length of which is immense compared with that of the axon of the bipolar cell. But that is simply due to mechanical morphological causes ; the optic nerve and tract are long in order to place the retina in a suitable position for being affected by light. We have no reason whatever for thinking that visual impulses, the differentiated nervous impulses or nervous changes which sweep along the optic fibre are in any way essentially changed from the time they leave the perikaryon of the retinal ganglionic cell until they reach their furthest terminals. Each optic fibre ends by linking itself with some cell, some nerve unit in one or other of the three nervous masses of which I spoke at the beginning, in the corpus quadrigeminum, in the corpus geniculatum, or in the pulvinar of the optic thalamus. Here again, a further differentiation, we may assume, takes place. Confining ourselves, for simplicity's sake, to one of the three bodies, say the corpus geniculatum, we find that the terminal of the optic fibre links itself to a cell or, rather, to more than one cell. The axon of that cell (or of each of those cells) either

proceeds direct as one of the so-called 'optic radiations' to the cortex of the occipital lobe, or, what appears to be the more ordinary, if not the only course, links itself to another unit, another nerve cell, also lying within the corpus geniculatum, it being the axon of this second cell which is prolonged as a fibre of the optic radiations. Possibly even still another unit may be intercalated in the chain, within the corpus geniculatum.

In any case, a differentiation, probably a large and yet subtle one, takes place in this corpus geniculatum, and the nervous impulses or nervous changes which are produced along the optic radiations are of a very different nature from those which travelled along the fibres of the optic nerve and tract.

The fibres of the optic radiations having reached the cortex in the occipital region of the brain (we may leave on one side for the present the topographical limitations of the region), link themselves to cells in that cortex, and, so far as mere visual sensations are concerned, the final differentiation takes place here. For, as I said at the beginning of this lecture, the integrity of the occipital cortex, and this part alone of the cortex, is essential for the development of visual sensations. Remove, destroy, or injure this part of the cortex, and this part only of the cortex, indeed, this part only of the whole nervous system, and blindness, or imperfect vision, is the result. Remove, destroy, or injure any other part of the nervous system, save and except this occipital cortex, and the nervous visual mechanism of which it forms the head, the development of psychical visual sensations, if affected at all, is affected in an indirect manner only.

The visual mechanism is a chain of nervous units beginning with the cone (or rod) and ending in the occipital cortex. The psychical event which we call a visual sensation is the culmination of a series of differen-

tiations which the simpler events begun in the cone undergo as they pass through the successive links of the chain.

What can be said about the several differentiations? Some writers, influenced by the experience that in monkeys and some other animals removal of the occipital cortex immediately produces total blindness, the absence of all visual sensations, seem from their writings to hold the view that the psychical feature is introduced into the whole business at the cortex, and at the cortex alone. Such writers use expressions which seem to imply that all the events which take place in the mechanism, in the retina, optic nerve and lower bodies are purely physical changes, unaccompanied by any psychical development, and that it is only when these purely nervous changes reach the cortex that they suddenly put on psychical characters, as if up to the cortex what was going on was mere invisible heat which in the cortex suddenly burst out into visible flame.

But if we turn to lower animals, such as rabbits, birds, and the like, we find that careful observers have found what appears to be unassailable evidence that these animals are influenced in a remarkable and complex manner by retinal impressions, even after the occipital cortex, and indeed the whole of both cerebral hemispheres have been removed. In such animals, while in this condition, something takes place in the cerebral structures still left in the corpora quadrigemina or optic lobes, for instance, which influences and guides the movements of these animals in a manner strikingly analogous to the guidance of movements by visual sensations. So strong is the analogy that the *onus probandi* must be considered as resting on those who maintain that the events taking place in the visual mechanism in this condition are of a wholly different character from those taking place when the mechanism is entire.

Moreover, when we come to inquire why, in the monkey and in ourselves, injury to or disease of the occipital cortex abolishes or interferes with visual sensations, we have to bear in mind the following important facts. Removal or disease of the occipital cortex in such cases has effects which are not confined to the cortex; the lower bodies, the corpus geniculatum, the pulvinar and, in part, the corpus quadrigeminum are secondarily affected; their nutrition and life is interfered with, they undergo degeneration. The life of the nerve cell in the corpus geniculatum, whose axon stretches away to end in the occipital cortex, is in some way dependent on the integrity of the termination of that axon in the cortex; cut away that termination and the whole unit suffers. In such cases the removal of the cortex means more than mere absence of the cortex, it means interference with the rest of the mechanism. The absence of visual sensations in these circumstances cannot be attributed to mere absence of cortex; it may be in part due to changes in the lower part of the mechanism—changes which early manifest themselves by functional deficiencies, and later on by visible structural alterations. Indeed, the difference between the effects of removing the cortex in the monkey and those of the same operation in the rabbit or bird may be simply an expression of the much closer dependence on each other of the several parts of the mechanism in the one case than in the other, the dependence being itself the outcome of a higher psychical development.

So close, indeed, is this dependence of the lower visual body on the cortex, so delicate the ties which bind them together, as to justify the doubt whether the nervous events which take place in this part of the visual mechanism are to be considered as of the same order as the more ordinary nervous impulses known to us by our studies on ordinary nerves. Some time back I gave a warning, that such an

ordinary nervous impulse must not be considered as the only kind of event even in an ordinary nerve. That warning may be emphasized when we are dealing with the structures of which I am now speaking We may perhaps go so far as to say that we probably err in supposing that a visual sensation is the result of a nervous impulse, a something with a definite length and amplitude of wave, sweeping up from the corpus geniculatum to the occipital cortex, leaving the one to pass to the other, and only producing its effect when it reaches its goal. It is more probable that the two structures, the cortex and the lower body, in some way work together, and that a visual sensation of a complete character is an expression not of the cortex being affected by something merely passing to it from the lower body, but of something passing to and fro between the two. If it be permitted to adopt a popular phraseology, we may say that the seat of visual sensation is not in the cortex alone, but in the cortex and the lower bodies.

Before, however, we consider this matter any further, let me turn to the cortex itself, to the occipital cortex. I will continue to use the general term "occipital cortex," because, in the first place, the topographical limits of the particular area of the whole occipital region which is specially concerned in vision has not, as yet, been exactly determined, and, in the second place, such topographical exactitude is not necessary for the theme which I have in hand. The dominant structural feature of the whole cerebral cortex is the multitude of linkages between dendrites and the terminal branchings of axons. And this is, perhaps, especially true of the occipital cortex. Cells of different form send out in various directions much-branched, far-reaching dendrites, and intertwining with the apparently inextricable tangle thus constituted run a multitude of branching axons, partly belonging to cells lying in the cortex itself, partly

coming up into the cortex from the white matter below and belonging to cells placed, it may be, in distant parts. In the occipital cortex, the axons of cells in the corpus geniculatum and its fellows, axons constituting the optic radiations, pass into this tangle and link themselves with the cortical cells. These cells, as I have said, are of different forms. Conspicuous among them, and especially numerous in the occipital region, are the "pyramidal cells," so-called from their shape, that of a pyramid sending out basal dendrites from the angles at the base and an extended apical dendrite from its apex. So crowded and conspicuous in the occipital cortex are these pyramidal cells, especially of the smaller variety, that we may probably, without great error, assume that these are specially concerned in vision, though we are not justified in excluding from the same labours the various other kinds of cells also present, into the detailed features of which I need not go.

We may assume, I say, that these pyramidal cells are concerned in vision. Whatever be the exact nature of the events taking place in the axons of the optic radiations, these reaching the terminal divisions of those axons in the cortex, affect in some way the dendrites of the cells with which those divisions are linked. We may say provisionally, that through the axons of the optic radiations these pyramidal cells are thrown into activity.

What can we say about that activity? Let me first of all insist on the fact that the axons of these cells all lead away from the part of the cortex in which the cells lie to some other part of the nervous system. If the apparently somewhat common view to which I alluded a little while back were correct, if the process of vision were such, that apsychical, simply neural events propagated along the lower tracts of the mechanism suddenly culminated in the cortex into psychical visual sensations, we should expect

to find in the occipital cortex cells possessing characters which we might regard as conspicuously receptive. If we examine the nature of the terminal organs in which axons are definitely known to end, on which they work, on which they spend their neural energies, producing something unlike their own actions, we find these to be either muscular fibres or epithelial glandular cells or analogous elements. If there were between the neural events of the axon in the optic radiations and the psychical labours of the cortical cell some such a difference as exists between the changes which constitute the nervous impulses of a spinal efferent nerve fibre and the changes which constitute contraction of a muscular fibre, or the secreting activity of a gland cell, and the view of which I am speaking seems to indicate such a difference, then, I say, we should expect to find in the occipital cortex, cells whose bodies, even if not of large dimensions, at all events possessed characters indicating that they were the seats of important specific activities.

As a matter of fact, we find no such cells, no cells whose bodies even suggest such specific characters. Indeed, here, as elsewhere throughout the nervous system, the cell body, the nucleus with its perikaryon exists, as I insisted upon in the earlier general discussion, for the good of the axon, and its characters seem to be determined by the work which the axon has to do. In illustration of this I might quote the fact that large conspicuous pyramidal cells, though scanty in number, are found in the occipital cortex. These, however, are not receptive cells, the workshops of psychical sensations; they are motor cells, or, more exactly, they are cells whose axons pass directly to motor mechanisms, and their relatively large size is a feature which seems common to, at least, most distinctly motor cells, and is probably connected with the fact that the axons of these are usually of con-

siderable length. The most common cell on the other hand in the occipital cortex, the one which we may assume is concerned in the development of visual sensations, is a small or moderate sized pyramidal cell.

Let me not be misunderstood here. I am not arguing against the absolute specific character of the cortical cell. On the contrary, as I insisted a little while back, the essential note of the whole nervous system is that in the chain of linked units, each unit is marked by specific features, by features unlike those of its predecessor or of its successor. What I am arguing against is the view that in the visual chain such specific characters are to be found alone in the cortical link, or are alone conspicuous in this. And I am perhaps arguing still more against the view that the cortical cell is, as it were, in any sense a terminal, even a temporary terminal link, where alone important psychical labours are commenced, all the preceding links being engaged in nothing more than obscure neural work.

Indeed, this cortical cell is but one link in a chain, with other links to follow. As I was saying, the axons, the essential part of all these occipital pyramidal cells (and of others not pyramidal), lead away from the occipital cortex to elsewhere. Their goal is threefold.

In the first place, some lead to cerebral structures lying below the cerebral hemispheres, to the corpus quadrigeminum and other bodies. Among these are the axons of the large motor cells of which I have just spoken ; and, indeed, all the axons taking this course are probably linked, by a course more or less short, with motor mechanisms, notably with the mechanisms for movements of the eyes, but probably also with others. Some few, we have reason to think, are the instruments for carrying out, through efferent action, changes in the retina, by which the receptive cones, and possibly other structures, are tuned to their work, but concerning this our knowledge is imperfect.

In the second place, others lead away to the cortex of the opposite hemisphere, forming part of that great band of fibres, the corpus callosum, which ties together the two halves of the brain. How far the "callosal fibres" are concerned in bringing it about that, while having two brains we have only one mind, or that, in vision in particular, our daily life makes us no sign of the fact that of the fibres coming from the retina half are gathered up into one hemisphere and the other half into the other, is a matter on which I must not dwell here.

In the third place, others, and those by far the most numerous, lead to other parts of the cortex of the same side. Such axons, known by the not very satisfactory name of "association fibres," link themselves by their terminals or collaterals with cells in some part of the cortex other than the occipital, with cells having functions other than those of the occipital cells. Accepting the general principles on which I dwelt so long, we may infer that whatever be the exact nature of the events which take place in such an "association fibre" from the occipital cortex, as the result of other and different events reaching the cell of which it is the axon, those events lead to events again different in the axon of the cell on which that association fibre impinges. I purposely say events in the axon, rather than events in the cell, meaning by cell the cell body; for those association cells are no more terminal cells than are the occipital cells; in the one and in the other the cell body, with its nucleus, and the dendrites are only means for securing the occurrence of events sweeping along the axon. Indeed, within the central nervous system there are no terminal cells, no terminal units at all. As I have now repeatedly said, the whole nervous system is a congeries of chains, some long, some short. In each chain, whether long or short, there is one kind of beginning, a sensory cell, generally a

modified epithelial cell, receptive of the external influence, the stimulus, and one kind of end, a muscular fibre, or a gland cell, or some analogous structure, something outside the nervous system itself, on which the terminals of the final axon play. Every cell within the whole nervous system, be it in the spinal cord or lower cerebral structures, be it in the cerebral cortex is, I repeat, essentially one link in the chain which begins in a sensory receptive cell, and ends in a motor or analogous effective cell. The fundamental action of the nervous system, whether the links be many or few, is government of the effective cell by the receptive cell; the most common mode of government is an activity of the effective cell in response to changes in the sensory cell. In the simplest form, where the chain consists of one link only, of one nerve cell intercalated between the receptive and the effective cells, where the activities of the whole mechanism are limited to mere degrees of activity of the nerve cell and to the specific activities of its two agents, the response of the effective cell to changes in the receptive cell is simple and direct. As link is added to link, each new link, with its differential characters, enlarges the potentialities of the whole mechanism, rendering the dependence of the effective on the receptive cell more and more indirect. In the simple mechanism, response of the effective cell to events in the receptive cell is almost imperative, and is largely shaped by those events. In the complex mechanism, not only the character of the response, but also when it comes or whether it comes at all, is determined mainly by what takes place in the chain of links. In the one case, the event is flashed straight across the one link; in the other, it is reflected and refracted among a multitude of links, until often it seems to be lost in the nervous system itself.

To this, the visual nervous chain is no exception. The primary fundamental use of the chain is to govern effective units, which are, in the main, muscular units.

Trace out the varied chain, and whether you follow the short loops or the long ones you will come back to a muscle or some analogous effective unit. Run along the optic fibre and tract to the corpus quadrigeminum, a short loop brings you back to ocular and other muscles (there may be a still shorter loop within the retina itself). Pass upward to the occipital cortex, a longer loop brings you back once more. Pass on from the occipital cortex along the association fibres first to one and then to another part of the cortex, loops, longer it is true, but still loops bring you back to muscle. During all this, at each link of the chain, the differentiation pertaining to each unit brings about a change in the nature of the events taking place. At the beginning we call the events simply neural. Later on we recognize them as psychical. As we have seen, we seem to have clear reason to conclude that in the occipital units the threshold of the psychical has been reached, but we have also seen reasons to think that it has not been reached at one jump, but rather by successive differentiations. We may infer that in the so called "associations" loops, further successive psychical differentiation is effected. And, indeed, positive evidence is being gathered that this is the case.

I must not enter fully into this part of my subject, since I have other points to dwell on; I must content myself with one example.

One of the muscular mechanisms with which the visual, nervous chain is connected is that of speech. When a person in reading speaks the word which he sees before him, a nervous machinery of many links intervenes between the image of the word thrown on the retina, and the muscular contractions which give rise to the sound of the spoken word. That machinery may be damaged by injury or disease in many ways, the chain may be broken in one or other of the many links. It may be broken in the following

way. The person may have no mere vocal difficulty whatever; the machinery for speech as speech, and this we have reason to think is made up of nerve units lying in the frontal region of the brain in one of the so-called frontal convolutions, may be intact. On the other hand, his mere visual sensations may be also intact: there may be every evidence that he "sees" everything perfectly, including the printed word. He is in this condition; he can pronounce the word, he can see the word, but he cannot pronounce the word as the result of seeing it. He can pronounce the word perfectly when the motive for speaking it is hearing it, or some other motive than the seeing it. Between the seeing and the speaking some link is snapped. I bring this "word-blindness," as it is called, to your notice because, in respect to it, we have evidence from cases of disease that the nervous link which is snapped lies in the cerebral cortex, not in the occipital area concerned in the development of visual sensations, not in the frontal convolution where the nervous processes which issue in the vocal utterance are marshalled, but in a limited spot of the cortex situate between the two, in what is called the angular gyrus. When this is damaged, word-blindness results, and the more the damage is limited to this spot, the more clearly the psychical defect appears as mere word-blindness. As we have seen, the occipital cortex is concerned in visual sensations. I might add that most probably it, too, is mainly concerned in visual perceptions. Not only are the crude sensations excited by the arrangements of black and white of the component letters developed by means of it in the manner which I have attempted to indicate, but by means of it also, or of some part of it most probably (I am speaking now of a matter of which our knowledge is very vague), in some way or other takes place the further psychical elaboration of the constituent sensations into the apperception of the word as a whole. But in order to

speak the word thus perceived some further psychical act is necessary; and the neural events which form the basis of this seem to be carried out by the "association" fibres which pass from the visual area of the occipital cortex to the other units in the area in the angular gyrus, and by those other units. We have here, then, an instance of at least two stages of psychical differentiation. And I might quote other instances.

I am aware that what I have just said is psychologically vague and imperfect. I do not pretend that it is anything more. But I think I may venture to say that, imperfect as it is, it seems to open up the possibility of our gaining, perhaps at no distant date, clearer knowledge. If I have carried you with me in my earlier arguments, we have gained this position, that in the visual neural chain from the retina to the occipital cortex, through the action of unit on unit, neural events in some way or other give rise to visual sensations. Somewhere in this chain the psychical threshold is distinctly passed; the neural event, the neural "thing" gives rise to, is accompanied by, manifests itself through conscious sensation. I am purposely vague in the use of words to denote the bond between the two. Nevertheless, the psychical event, so far as we can see, is commensurate in magnitude with the neural event, follows it as effect follows cause. But if particular structures, particular units are thus specially associated with the simple elements of psychical life, namely with sensations, it is not too much to conclude that the mere complex psychical factors are similarly associated with particular structures, and that in some such way as the initial purely physical effect of light on the front part of the cone, by means of successive differentiations of that initial effect, through a chain of units gives rise to the undeniably psychical effect, so by successive differentiations through complex chains of

units, the simple sensation gives rise to "higher" psychical life. What is wanted is a careful analysis (as yet only just begun) of the complex tangle of neural units which make up the brain, an analysis at once physiological and anatomical. And what perhaps is wanted even more is that this objective analysis should be guided and, if need be, corrected by an adequate subjective analysis on the purely psychological side, for hitherto these have not been found too often in company. The instance of word-blindness on which I just now dwelt, and I might bring forward others, gives us, I say, great hope for the fruitfulness of future inquiry.

I must now turn to another aspect of my subject. Leaving the higher psychical development, and returning to the general characters of simple sensation, I will ask your attention to the influence of various circumstances and conditions on the production of psychical effects.

I have spoken of the visual mechanism as a bundle of chains of units. But it must not be inferred from this that such chain in the optic bundle is wholly separate from its neighbours. It is not the case that one cone unit is linked to one bipolar unit only in the retina, this to one ganglion unit only, this to one unit only in the corpus geniculatum, and this to one unit only in the cortex, so that in the cortex each cone (or rod) is represented by one unit only, apart from and distinct from neighbouring units. On the contrary, there is a mingling at the very outset; each cone fibre is linked to and can influence more than one bipolar unit. The mingling is repeated at each successive link, and is especially prominent in the corpus geniculatum and its allies. Now, when two parts of the retina are stimulated by light at the same time, the condition that two distinct sensations are produced is that the two points should be separated

by a distance at least not less than the distance between two cones. Had the visual mechanism been such that each chain of units, with a cone at one end and a receptive cortical cell at the other, was quite separate from its neighbours an anatomical explanation of separate sensations might have seemed possible. But such an explanation, quite apart from all other objections, is rendered impossible by the mingling just spoken of. Obviously, even supposing that a single cone can be stimulated alone, all its neighbours remaining at rest, the effect will become a diffuse one as it is propagated along the mechanism; and the effects of the simultaneous stimulation of two cones, even at some distance apart, will overlap. I will not attempt to discuss what are the conditions which really determine that two sensations shall be distinct. I have brought these matters forward because they seem to further illustrate the incorrectness of the view, that a sensation is brought about by nervous impulses reaching some cortical station, and there becoming suddenly transformed, as if there were a sort of mosaic of sensations corresponding to the retinal mosaic. It would seem probable that, in the development of any visual sensation, several elements, several units for example of the corpus geniculatum are concerned. Further, the phenomena of simultaneous contact shew that all those elements are not concerned in the same way; in some, effects are produced which appear the very opposite to those produced in others. And, indeed, there seem some reasons for believing that no one spot of the retina can be affected by light, without the whole mechanism, without the elements connected with the whole retina, being also affected in some way or other at the same time.

Assuming the truth of the view which I put before you at an early part of the lecture, that differentiation of action takes place not in any part of a unit rather than in any

other but at the linkage of unit with unit, each unit acting as an individual differentiated whole, the circumstances attending linkage deserve attention. As we have seen, the mode of linkage, which, if not universal, is at least usual, is that the terminals of an axon (of the stem or of a collateral) link with the dendrites or perikaryon of another unit, so that the axon of one unit works on the axon of another unit, not directly, but through the means of the dendrites or perikaryon, the direction of activity being centrifugal away from the nucleus along the axon. We have no evidence of the terminals of one axon linking on to the terminals of another axon so as to suggest that an axon can work directly on an axon, or start an action which proceeds centripetally towards the nucleus. This however is perhaps not a matter of vital importance. We came to the conclusion some time back that the unit acts as a whole, that the axon does not act apart from the rest of the unit, and that dendrite and perikaryon act for and through the axon. Hence we may further conclude that, to whatever part of one unit another be linked, the effect, which is an activity of the axon, is in the main the same.

We have further seen that a linkage is in the vast majority of cases, if not universally, a thing of contact not of fusion; that is to say there exists an obvious gap between the nervous material of the one unit and that of the other. And we may conclude that the existence of this gap is one of the conditions determining the differentiation of action which takes place or begins at the linkage. Such a palpable gap is not essential to the occurrence of differentiation. That is the result of the individuality of each of the two linked units, is the outcome of the fact that the powers of the one unit are not identical with those of the other. Even in the case where one unit seems to fuse wholly with the other, where the best optical analysis can detect no sepa-

ration between the material of the two, general considerations would lead us to conclude that a line of demarcation does exist on the one side of which the molecules belong to the one unit and obey the one nucleus, and on the other side belong to the other unit and obey the other nucleus. In no tissue, whether animal or vegetable, is an instance known of a common border-land between two cells, belonging to both cells and governed by the nuclei of the two. Hence we may infer that apparent structural fusion does not imply functional fusion, that the molecules on one side of the functional line of demarcation behave or may behave differently from those on the other side. We may still infer, however, that a palpable structural gap, though not essential to the mere occurrence of differentiation, must in some way determine the extent or character of the differentiation. Knowing, as we do, so little of the actual nature of the molecular changes which underlie neural events, our ideas as to how such an obvious gap affects the transference of events from one unit to another must necessarily be vague and obscure; but we cannot do otherwise than suppose that the transference is different when it proceeds along a tract of nervous material, continuous as mere nervous material though changing in character where the tract leaves one unit to join the other, from what it is when it has in some way or other to pass across a bridge composed of material not nervous at all. As we have seen, the one objective token of a nervous impulse is an electric change, and though nervous events cannot be identified with ordinary electric events as at present known, yet the similarity of nervous events to electric events is greater than their similarity to any other physical events; and we may perhaps, leaning on this similarity, illustrate the possible influence of such a bridge of non-nervous material in the course of a nervous tract by saying, that the difference which it introduces is

analogous to that between electric induction and conduction. But this, it must be remembered, is nothing more than a vague illustration.

I have alluded to this bridge because, recently, great importance has been attached to the possibility of the transference of one unit to another being directly and boldly modified through the bridge being made longer or shorter by the physiological processes of contraction and relaxation of the nervous material. In the case of many cells, notably the pyramidal cells of the cortex, the dendrites are furnished with minute, rod-like appendages, sometimes spoken of as "thorns." Now, making every allowance for changes in appearance being simply the result of differences in the mode of preparation of microscopical specimens (and the technique of the microscopical study of nervous structures is undoubtedly complex and uncertain), it seems to be established that these minute appendages while at one time conspicuous, may be at other times inconspicuous, as if they had been withdrawn or retracted. And it is maintained that the retracted condition may be brought about by influences, generally rough and powerful ones, such as electric shocks or poisons brought to bear on the nervous system, or even on the organism as a whole. The retraction of such an appendage will increase the length of the bridge spoken of above, or will establish a bridge where no obvious one existed before, and hence may be supposed largely to modify, or even to abolish altogether the transference of neural events from one unit to another. And, indeed, some writers have boldly used this phenomenon as a mechanical explanation of neural, and so, of psychical events. It has been suggested, for instance, that, as the result of fatigue, these appendages to the dendrites of a cortical cell are retracted after prolonged activity of the cell, that the transference of neural changes from the

linked axon is thereby interrupted, and the activity of the cell suspended, and that this is the basis of sleep.

I am free to confess that, so far as I know, no adequate proof has, as yet, been offered, that under ordinary, what we may call natural, influences any such retraction does take place. Moreover, while it is true that the power to change its form, as seen in amœboid movement and in muscular contraction and relaxation, seems a fundamental attribute of undifferentiated living matter or protoplasm, as it is sometimes called, it is also true that the differentiation of protoplasm means the exaltation of certain powers at the expense of others; and in that extreme differentiation which protoplasm undergoes in being fashioned into nervous material, especially into the nervous material whose activity is manifested by psychical events, we should have expected that the law of economy would have extinguished, even to almost the last remnant, the lower function of mere movement. Indeed, it seems probable that the diminution or suspense of neural changes, especially those manifesting themselves in psychical events, would be achieved by diminishing the molecular changes, to carry on which the material is so exquisitely fashioned, rather than still burdening that material with the grosser labour involved in a change of form. We should expect a cessation of activity in a unit to be brought about by dulness of the appendage to a dendrite towards the influences exerted by the terminal of an axon, a dulness which is a mere phase of its normal molecular processes, rather than by bodily retraction, which must call into play molecular processes of a wholly different nature.

Indeed, this hypothesis of gross change of form as an explanation of psychical events may be objected to on the very ground that it leads us away from a line of thought which is probably far more fruitful, namely, that

of the delicately varied and exquisitely cared for nutrition of the nervous unit, in view of the molecular labours, other than those issuing in change of form, which it has to carry out.

I have just urged that the fine differentiation of nervous material entails the suppression of the fundamental primeval power of change of form. I may now add that the differentiation entails the loss of another fundamental property, that of reproduction. While in other tissues, notably in the skin and muscles, old units, old cells worn out by use or by divers influences are replaced by new ones, a fact broadly but incorrectly expressed in the popular statement that the whole body is renewed every seven years, the evidence which we possess goes to show that such a regeneration, that the appearance of new units by birth from old ones, comes to an end at an early period of life in the case of the nervous system. Take away a piece of skin, of bone, or of connective tissue, new stuff of the same kind makes good the loss; but a piece of brain once lost is lost for ever; the cells, the units which made it up, are never replaced. Examine almost any tissue of the body other than that of the nervous system, at almost any period of life, and you will find evidence in the changes going on in the nuclei that old cells are giving birth to new ones. Examine in the same way the nervous system for like signs, and after a certain date, which we may probably fix as that of very early youth, you will find none. At a very early date the installation of nervous units is completed; after that no new units make their appearance. So far as the number of units is concerned, the machinery is a finished one. All the growth, all the increase of complexity, henceforward possible, is accomplished not by the introduction of new units, but by the extension and development of those already installed.

This, at first sight, seems inconsistent with the broad experience that the work of the nervous system, above that of all other parts of the body, becomes richer and fuller as life advances. But it is only inconsistent with the view that in the course of life there come to the individual new powers, the outcome of new units of machinery. It is not inconsistent with the view that new powers are only the development of the potentialities of old units. And, indeed, the failure to produce new units brings as a recompense favourable conditions for the development of such potentialities. In the nerve unit, the nerve cell, the, to us, occult energies—which in another tissue lead to the cell sacrificing itself in order to produce its kind—are selfishly limited to the increase of its own mass and powers. Barred from reproduction, the nerve-cell is conspicuous, on the one hand, for its power to extend parts of its body for enormous distances from its central nucleus, and to repair any parts of itself which may be damaged or injured; and, on the other hand, for the facility with which it adapts its growth to the circumstances of its life.

Thus, the axon of a cell in the lumbar cord, or the fibre, call it axon or dendrite, belonging to a cell in the ganglion of the root of a lumbar nerve, may stretch away from the nucleus by which its life is governed right down to the toes, and, moreover, if divided close to the nucleus so that the whole length dies away, will in a very short time be renewed from the nucleus outwards to its very end. Take away the nucleus and perikaryon, no new nucleus, no new cell ever replaces the lost; but leave the nucleus, and a great long axon, many times exceeding the perikaryon in bulk, may be renewed again and again.

So, again, while, as I have said, we have no evidence that after a certain date any new nerve cell ever makes its appearance, we have abundant evidence that a nerve cell, simple in form at its installation in early life, may

grow in course of time into a very complex figure, and, moreover, that the extent and character of its growth is to a large extent determined by the demands for action made upon the cell by the incidents of life. In all the tissues of the body we may trace the influence of exercise and the stimulating effect of the demand for action; but these are seen in their highest form in nervous tissue and most conspicuously perhaps in the nerve cells of the cerebral cortex. The nutrition of every tissue of the body is determined by two factors, by the quantity and quality of the blood supply and by the activity of the tissue itself. But whereas in most tissues the former is the predominating factor, in nervous tissue and especially in the cortical cells, it is the latter which rules. As we have incidentally seen, the nerve unit, so soon as it is cut off from the play of its fellows upon it, begins to droop, however rich and full the blood stream which reaches it; it droops the sooner and the more, the quicker was its life before. The potentialites of the unit may have their source in the blood supply which bathes it, but its actualities are determined by the calls made upon it.

This, in fact, is the physical basis of education. The material of the nerve cell renouncing the grosser duties of bodily movement, of secretion, that is to say the production of chemical substances destined for the good of units other than itself, and of reproduction, concentrates its energies of nutrition on making itself responsive by inner molecular movement to the finest changes in its surroundings. It is the seat of a finely balanced nutrition wholly exceeding that of any other tissue. Every incident of its life stirs that nutrition, which indeed is directed to being so stirred; and, moreover, while producing an immediate effect, leaves a trace behind. When the blows of external influences are repeated often enough, especially if they be heavy enough, the effects are mani-

fested in the grosser changes which we call growth. But such large effects are nothing more than the summation of smaller changes; to produce the total each contribution must have brought its share. And we shall probably not err in supposing that every influence brought to bear on a nerve unit produces an effect which lasts far beyond the passing functional activity. When light falls on sensitive retina for a moment only the effect on the higher parts of the visual mechanism may be traced long afterwards, under favourable circumstances, as a gradually fading series of images alternating with rests or rather with reversions, and even when the effects have fallen below the threshold of consciousness, and thus seem to have passed away, a study of the results of a fresh stimulation shows that the machinery is not yet at rest, is not as yet what it was before. Moreover, the finer our means of testing, the longer may we trace out the effects. Yet, in this visual mechanism which supplies the earlier links of the nervous chain for the production of psychical effects, which has to be used again and again in order to feed the higher, more distinctly psychical links, there must, we may suppose, be agencies at work tending to wipe out all previous effects in order to prepare for new events. In the higher links the need of such tergative agencies will, we may further suppose, become less and less. If so, in them we may fairly expect that the effect of an influence once brought to bear will last far longer, will last long enough, may I say, to give us a glimpse of seeing what may be the physical basis of the psychical fact of memory.

One word more. In the lower tissues, in undifferentiated protoplasm, in muscle and the like, spontaneous activity, automatism seems to be the direct outcome of nutrition, the direct effect of the blood supply working on the molecular machinery, and to be independent of the

play of external influences on the tissue. But if there be any truth in the views which I have been urging upon you, we cannot transfer this conception to the working of the brain. If in nervous tissue, as I have urged, the influence of the blood supply is wholly subordinate to the influences of incidents, the more so the higher the elements, we must attach but little importance to the play in it of such a direct nutritional automatism. We must regard that psychical spontaneity which we call the will, as, at least in the main, the outcome of complex influences.

Manchester Memoirs, Vol. xlii. (1898), *No.* **13.**

XIII. Contribution to our Knowledge of the Marine Fauna of the Falkland Islands.

By Edith M. Pratt, B.Sc. (Vict.).
Research Student in Zoology at The Owens College.

ERRATA.

III. Lamb, *On Waves.*

p. 4, equation (19); *read*

$$\lambda/\lambda_{,,}.$$

p. 4, equation (20); *read* N_{∞}^{2} in second member.

p. 16, equation (89) should precede the last two lines of type.

months of September and October, 1896, and the specimens may be regarded as forming a typical common shore collection of that region, the shore at Hill Cove being sandy with small rocks.

Through the kindness of Mr. Standen, I have also had access to a collection of Mollusca, on some of which grew various Bryozoa, made by Miss Cobb at Lively Island, Falklands. These were also shore forms.

In the Collection were the following species of Bryozoa:—

December 14th, 1898.

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[*Communicated by Professor* S. J. Hickson, F.R.S.]

Received and read March 22nd, 1898.

The work in connection with this paper has been done in the Zoological Laboratories of the Owens College, Manchester, under the kind supervision of Professor Hickson.

I must thank Dr. Harmer, of Cambridge, for his great kindness in placing at my disposal his collection of Bryozoa, and for his kind aid in identifying certain species.

My thanks are also due to Mr. Kirkpatrick for assisting me in the examination of the "Busk" Collection of Bryozoa, at the British Museum.

The material at my disposal was collected by Miss Blake, at Hill Cove, West Island, Falklands, during the months of September and October, 1896, and the specimens may be regarded as forming a typical common shore collection of that region, the shore at Hill Cove being sandy with small rocks.

Through the kindness of Mr. Standen, I have also had access to a collection of Mollusca, on some of which grew various Bryozoa, made by Miss Cobb at Lively Island, Falklands. These were also shore forms.

In the Collection were the following species of Bryozoa:

CHEILOSTOMATA.

I. *Beania magellanica* MacGillivray
= *Diachoris magellanica* Busk,
Brit. Mus. Cat., I., p. 54.

II. *Beania costata* MacGillivray
= *Diachoris costata* Busk,
Challenger, Vol. X., *Polyzoa*, p. 60.

III. *Cellaria malvinensis* Busk
= *Salicornaria malvinensis* Busk,
Challenger, Vol. X., *Polyzoa*, p. 91.

IV. *Cellepora pustulata* Busk,
Challenger, Vol. X., *Polyzoa*, p. 200.

V. *Cellepora pumicosa* Busk, var. *eatonensis* Busk,
Challenger, Vol. X., *Polyzoa*, p. 201.

VI. *Cribrilina labiosa* Busk
= *Lepralia labiosa* Busk,
Brit. Mus. Cat., II. p. 82 ;
Challenger, Vol. X., *Polyzoa*, p. 133.

VII. *Cribrilina monoceros* Busk,
Challenger, Vol. X., *Polyzoa*, p. 133 ;
Hincks, *Ann. Mag. Nat. Hist.*, (5) VIII., p. 57.

VIII. *Lepralia adpressa* Busk, *Brit. Mus. Cat.* II., p. 82;
Hincks, *Brit. Mar. Polyzoa*, p. 307.

IX. *Membranipora membranacea* Linn.
Hincks, *Brit. Mar. Polyzoa*, p. 140.

X. *Micropora uncifera* Busk,
Challenger, Vol. X., *Polyzoa*, p. 71.

XI. *Microporella ciliata* Pallas.
Hincks, *Brit. Mar. Polyzoa*, p. 206.

XII. *Microporella malusii* Audouin.
Hincks, *Brit. Mar. Polyzoa*, p. 211.

XIII. *Mucronella tricuspis* Hincks,
Ann. Mag. Nat. Hist., (5) VIII., p. 66.

XIV. *Schizoporella hyalina* Linn.
Hincks, *Brit. Mar. Polyzoa*, p. 271.

XV. *Schizoporella hyalina* (variety).

XVI. *Smittia landsborovii* Johnston.

Hincks, *Brit. Mar. Polyzoa*, p. 341.

XVII. *Porella tridentata*, sp. nov.

CTENOSTOMATA are only represented by some badly preserved fragments of the genus *Bowerbankia*, the species of which I have been unable to identify.

Of the preceding species, two are cosmopolitan in shallow water and are also found in some regions in deep water; this fact is referred to later.

I. *Microporella ciliata*, on weed, among debris, and on *Mytilus*.

II. *Schizoporella hyalina*, on weed and shell (*Photinula*).

It is noteworthy that both these forms occur on weed.

The following species are common to the northern hemisphere, including Britain, and the Falklands:—

I. *Lepralia adpressa*, on shells (*Photinula violacea* and *Trophon muriciformis*).

Habitat: Britain (Torbay, Guernsey, Hastings). Mediterranean (Algiers, Naples, Bay of Gibraltar). Australia. Chiloe. Falklands. Mazatlan.

Moderate to deep water. Fossil—Italian pliocene.

II. *Membranipora membranacea*.

Habitat: Britain; universal and abundant. Hvidingsoe. Hougesund (Norway). Roscoff. Finisterre (France). Adriatic. New Zealand. Australia.

Range in time—coralline crag. Palæolithic.

Occurs only in temperate seas in shallow water.

III. *Microporella malusii*.

Habitat: Britain (widely distributed and abundant). Gullmaren. Bahusia, 10-20 fath. Bergen. Fin-

mark (Norway). Greenland. Mediterranean. Adriatic. France (S.W.). Black Sea. South Patagonia, 48 fath. Tierra del Fuego. Falklands. Valparaiso. New Zealand.

Fossil—coralline crag, on *Terebratula*. Older pliocene. (Castrocara).

The following occur in north and south temperate seas, but not in Britain, nor the tropics :—

I. *Beania magellanica*, growing on an Ascidian (*Molgula gregaria*).

Habitat: Adriatic. Australia, 2-10 fath. New Zealand. Kerguelen. Cape Horn. Falkland Islands.

It appears to occur only in shallow water.

II. *Cellepora pustulata*, on *Patella venosa*.

Habitat: Island of Capri (Italy). Victoria (Australia). New Zealand. Marion Island.

The specimen, though fairly large, is much water-worn.

It is interesting to note that the only known northern habitat of these two species is the Mediterranean.

The following species is the only one which occurs in north and south temperate and cold seas, *and in the tropics* (Florida).

Smittia landsborovii, on shell (*Trophon muricijormis*).

Habitat: Britain. Florida. Greenland. South Africa. Falklands. Australia. Arctic Seas. Davis Strait.

Fossil—var. *crystallina*—Scottish glacial deposits.

The following species occur only in the southern hemisphere :—

I. *Beania costata*, on weed, in shallow water.

Habitat: Australia. Kerguelen. Cape Horn. Falklands.

II. *Cellaria malvinensis*, erect, in fairly shallow water.

Habitat: Petane (New Zealand). Strait of Magellan, 45 fath. South Patagonia. Victoria (Australia). Kerguelen. Marion Island. New Hebrides (S. Pacific), 70 fath. Cape Horn. Falklands. Fossil in tertiary of New Zealand.

III. *Cellepora pumicosa*, var. *eatonensis*, among debris, and encrusting shell.

Habitat: Kerguelen, 28 fath. and 45 127 fath. W. of S. America, 45° 31′ S., 78° 9′ W Falklands.

IV. *Micropora uncifera*, on weed.

Habitat: Mid South Atlantic. Tristan D'Acunha. Nightingale Island. Inaccessible Island. Cape Horn.

V. *Cribrilina labiosa*, on shells (*Mytilus magellanicus* and *Terebratula*).

Habitat: Falklands. Simon's Bay (Cape of Good Hope).

VI. *Cribrilina monoceros*, on *Mytilus edulis*.

Recorded from :—

Mid N. Pacific 3,125 fath. Australia, 35 fath. New Zealand. Marion Island. Strait of Magellan, 175 fath. Between Strait of Magellan and Falklands. Bass Strait. Cape Horn. Falklands, 12 fath.

Fossil: tertiary deposits. Bairnside, Victoria (Australia). Napier and Petane (New Zealand).

VII. *Mucronella triaspis*, on shell (*Mytilus ungulatus*).

Habitat: Australia, 38 fath. Simon's Bay (Cape of Good Hope). Prince Edward Island. Tierra del Fuego. Chiloe. Falklands, 5-12 fath. S. America.

VIII. *Porella tridentata*, sp. nov. On shell (*Euthria antarctica*) Falklands.

Of the foregoing list of species, the following have not, I think, been hitherto recorded from the Falklands :—

1. *Cellepora pustulata.*
2. *Lepralia adpressa.*
3. *Membranipora membranacea.*
4. *Smittia landsborovii.*
5. *Micropora uncifera.*
6. *Microporella ciliata.* The variety *personata* was recorded by Darwin from the Falklands, but not the true species.

Of 16 species of Bryozoa in this collection, eight have been found only in the southern hemisphere. Five have been found in the north and south temperate regions. One occurs in the north and south temperate regions and in the tropics, and two are cosmopolitan.

Notes on the Species of Bryozoa in this collection.

The zoœcia of *Microporella ciliata* seem larger than those of the British specimens. In structure I think they more closely resemble those of the Californian specimens.

Lepralia adpressa var. Busk. The surface of the zoœcium is strongly grooved, as described by Busk of the species occurring at Chiloe (*see* Busk, *Brit. Mus. Cat.*, Vol. II., p. 82), but there are, in addition, certain large pores which occur round the margin of each zoœcium, at the base of each triangular furrow (*see Figs.* 1 and 2). These pores I have also seen in Busk's "Chiloe" specimen at the British Museum, but they are neither so numerous nor so well marked as in my specimen.

Avicularia (*Fig.* 3) of two kinds occur, which have not hitherto been described; one appears to be the ordinary beak-like form, but is often slightly irregular in shape (*Fig.* 3, *a* and *b*); the other is circular in outline, with a spatulate mandible (*Fig.* 3, *c* and *d*). The avicularia are very irregularly distributed over a colony; sometimes five or six neighbouring zoœcia possess one

or even two, whilst not one of the remaining zoœcia of the colony bear any.

In one or two cases, knobbed cells are seen (*Fig.* 1, *a*), which are characteristic of the British species (*see* Hincks, *Brit. Mar. Polyzoa*, p. 307). I have seen no trace of an ovicell.

Porella tridentata, sp. nov.

Zoœcia hexagonal, separated by fairly deep linear furrows; surface convex and punctured by large irregular pores which, in some cases, are definitely arranged round the margin.

Secondary orifice horse-shoe shaped or inversely subtriangular, with a lateral raised collar meeting in a sudden depression behind (*Fig.* 4, *b*), often a sinus in front, containing a small avicularium with a rounded mandible (*Figs.* 4 and 5, *b*). In many cases a spatulate avicularium is present to the right of the secondary orifice (*Figs.* 4 and 5, *a*).

Deep down in the orifice can be seen a large median denticle with two lateral ones (*Figs.* 4 and 5, *c* and *d*); because of this feature it has been thought fit to call the species "*tridentata*."

The ovicell (*Fig.* 5, *Ov.*) is semicircular in outline, convex in front, somewhat granular, with one or two groups of irregular punctures.

Zoarium encrusting shell (*Photinula violacea*) and of a dirty pink colour.

Porella tridentata is somewhat like *P. concinna* (Hincks, *Brit. Mar. Polyzoa*, p. 323). It differs from the latter in having two lateral denticles in addition to the median one which is present in *P. concinna*. It is also somewhat larger, and the pores are bigger and irregular in shape. The spatulate avicularium appears to be constant in position, while the general shape of the secondary orifice seems to be somewhat different.

P. tridentata differs from Jullien's *P. malouinensis* (*see Cap Horn Expéd.*, p. 57) in that the pores are larger and fewer in number. *P. malouinensis* appears to have no spatulate avicularium or denticles, and the secondary orifice is somewhat different. The ovicell agrees with Jullien's description of that in *P. malouinensis*, which, however, he does not figure.

A consideration of the geographical distribution of the Bryozoa in this collection from the Falkland Islands, is of special interest at the present time because of the controversy about the origin of the north and south extra-tropical marine faunas.

Murray* is of opinion that "if there were once a nearly universal climate over the whole of the ocean, then it is possible that there was a universal littoral marine fauna." When cooling set in at the Poles, then the animals with pelagic larvæ would be killed out, or be forced to migrate towards the warmer tropics. By limiting their reproductive process to the summer season, some of the organisms with free swimming larvæ would live on in the temperate regions. With the disappearance of the shallow-water fauna from the polar regions, its place would be occupied by organisms from the deeper mud line, few of which have pelagic larvæ. In this way the similarity and, in some cases, identity between the polar faunas, and the likeness of many shallow-water polar animals to deep-sea species, might be explained.

The cooling of the waters at the Poles would cause vast migrations of forms towards the warmer seas, where metabolic changes would be greater; this would cause the

* Murray "On the Deep and Shallow-water Marine Fauna of the Kerguelen Region of the Great Southern Ocean." (*Trans. R. Soc. Ed.*, Vol. 38 (1896), p. 343; also *Challenger Summary of Results.*)

struggle for existence to be intensely severe in the tropics, and would result in a rapid formation of species, while many would become extinct. On the other hand, the metabolism being less in the temperate and colder waters, and the struggle for existence being less severe here than in the warmer waters, there would be less tendency for the species to become modified, and many would remain true; hence the similarity between the North and South temperate faunas.

Ortmann,* whilst acknowledging the possibility of the existence at one time of a universal fauna, contends that the cooling at the Poles did not arrest the capability of variation, but that the bipolar forms now existing must have passed through a greater range of variation than the tropical forms; in other words, that the tropical fauna has remained more or less true, while the temperate and bipolar forms are derivatives of ancestral forms.

He admits that a form with a well-developed adaptative faculty may have passed through all the varying conditions of temperature, etc., without becoming extinct. The changes due to climatic conditions being similar at both Poles, two faunas resulted from the primitive material, one Arctic, the other Antarctic.

He also holds that the likeness between the north and south polar faunas, is in many cases a *secondary reappearance*, and is dependent on the adaptative capability of the inhabitants of the Poles. He does not think that identical species can result in both polar seas *from a common descent*. He maintains that an exchange of both polar forms can take place *through the deep sea*, on the ground that, among Crustacea, the cosmopolitan genus *Pontophilus* shows a decided tendency to retire into deep

* Ortmann "Ueber 'Bipolarität' in der Verbreitung mariner Thiere." *Zool. Jahrb.* (*Abth. f. Syst.*) *Bd.* 9, (1896), p. 571.

water, but only occurs in the tropics in deep water. He suggests that many forms which have been recorded from northern and southern seas, but not from the tropics, may occur in the tropics *in deep water* and have consequently escaped capture.

Ortmann further maintains that the migration of forms may take place from the northern hemisphere through the tropics, to the southern hemisphere along the west coasts of America and Africa, because of the comparative low temperature in tropical regions along these coasts. This is confirmed in the Decapods, and the reverse—*i.e.* the migration of forms from the southern to the northern hemisphere—in the case of the Isopod *Serolis*.

Before discussing the bearings of these two theories, it would be useful to consider the distribution of the genera in the collection.

The genera represented are:—

CHEILOSTOMATA.

Beania, *Cellaria*, *Cellepora*, *Cribrilina*, *Lepralia*, *Membranipora*, *Micropora*, *Microporella*, *Mucronella*, *Schizoporella*, *Smittia*, *Porella*; and, among the CTENOSTOMATA, *Bowerbankia*.

All the species of *Beania*, with one exception (*B. hirtissima*), occur north and south of the tropics in temperate regions, but not within the tropics. *B. hirtissima* has been recorded from Cape Verde Islands, which lie within the tropics. All the species, except the British *B. mirabilis*, occur in shallow water.

The genus *Cellaria* is cosmopolitan. It occurs in deep and shallow water in the temperate zone. The depths at which it occurs in the tropics I have not been able to ascertain. It occurs in the fossil tertiary strata.

Cellepora. The *Challenger* obtained 30 or 31 species

of this genus, of which the North Atlantic yielded three, from depths varying from 51-400 fath.

The South Atlantic yielded 9 species, 5-600 fath.
„ Kerguelen region „ 6 „ 20-500 „
„ Australian „ „ 12 „ 2-40 „
(One species, an aberrant form, doubtfully referred to this genus, was found in 2,600 fath.).

The North Pacific region, 4 species, 10-30 fath.
„ South „ „ 2 „ one from 45 fath., the other from 1,325 fath.

The genus is cosmopolitan, and appears to belong to shallow water, yet evidence shows that it has a wide bathymetrical range.

Cribrilina. This genus inhabits north and south temperate regions, but only one species (*C. floridana*) has been recorded from the tropics (Gulf of Florida). The genus is fossil, occurring in the French cretaceous, Austro-Hungarian miocene (coral and red crag), Italian pliocene, boulder clay (Wick).

The species *C. monoceros* is notable in that it occurs in very shallow as well as in very deep water. Off the west coast of the extreme south of South America it has been found at a depth of 1,325 fath., in the North Pacific at a depth of 3,125 fath., Strait of Magellan 25 fath., Tierra del Fuego and Patagonia 19 fath., Cape Horn 40 fath., Falklands 4-12 fath. My specimens were picked up on the beach. The facts of its occurring in the tertiary deposits, its presence in the north and south temperate regions, and its absence from the tropics, tend to support Murray's argument, according to which *Cribrilina* may be looked upon as a true representative of a primitive, universal, marine, littoral fauna.

On the other hand—and this is supported by the fact that this species does occur in very deep water elsewhere—

it may be that this species exists in the tropics at great depths, and has thus escaped capture.

Lepralia. This genus occurs in the north and south temperate zones, and within the tropics; all the deep-sea forms occur in the temperate regions; the forms living in shallow water occur in the tropics as well as in the temperate regions. This is rather interesting, for it shows that the tropics do not form an insuperable barrier for all species, between the two temperate zones. Then, again, according to Ortmann's view, one would expect to find the deep-sea forms nearer the Equator, if the deep sea affords a passage between the two temperate zones.

The species *L. adpressa* occurs north and south of, but not within the tropics, in shallow and moderately-deep water. It occurs fossil in Italian pliocene, Austrian miocene, and tertiary formations at Reggio (Italy). The distribution of this species gives evidence in support of Murray's view.

Membranipora. The genus is cosmopolitan, chiefly in shallow water, but it also occurs in deep water.

M. albida, Tongatabu (Pacific), 21°S., 18-20 fath. Bermuda, 38°37′N., 450 fath. Singapore.

M. crassimarginata, Bass Strait, 38-85 fath. Heard Island, 75 fath. Tristan D'Acunha, 110-150 fath. Gulf of Florida, 13-60 fath.

M. multifida, Cape of Good Hope, 450 fath. Challenger station 320, 37° 17′S., 600 fath., green mud.

It is notable that the species occurring at great depths are found only in temperate regions. The *tropical* forms occur in *fairly shallow* water.

Membranipora membranacea occurs in north and south temperate zones, but not within the tropics.

Micropora. Genus extends back at least to the chalk period. It occurs in north and south temperate zones,

as well as the tropics, in shallow to fairly deep water (greatest depth recorded, 150 fathoms). The species *M. uncifera* is recorded only from the southern hemisphere.

Microporella. Genus cosmopolitan.

Microporella ciliata is also cosmopolitan; the specimens taken at greatest depths have been limited to temperate regions, namely: Bahusia, on the Falmouth and Lisbon cable, 47° N., 89-205 fath.; and the coast of Norway, 300 fath. The tropical specimens occur in fairly shallow water.

The species *M. malusii* occurs north and south of, but not within, the tropics in fairly shallow water (10-50 fath.). It occurs fossil; coralline crag, older pliocene (Castrocaro).

Mucronella. The genus is cosmopolitan, from fairly deep water, but the species *M. tricuspis* appears to be restricted to the southern hemisphere, from shallow to fairly deep water, 12-150 fath. Fossil—tertiary—New Zealand. The species occurring at the greatest depths occur also in temperate regions, with one exception—Challenger Station 122, off East coast of South America, 9° 5′ S.; the species *M. castanea* occurs from 32-400 fath., and, with this exception, all other tropical species occur in fairly shallow water. Many of the species of this genus are fossil, occurring in coralline crag, middle pliocene, upper pliocene, palæolithic, Scottish glacial deposits, &c

Schizoporella. The genus is cosmopolitan. The species *S. hyalina* is cosmopolitan, it occurs on shells, stones, weed, etc, from shallow to deep water, it is fossil, and occurs in coralline crag, Scottish glacial deposits, post-pliocene deposits (Canada). Greatest depth: of species 100 fath. (Davis St.), of the genus 300 fath. (off Norway).

Both the cosmopolitan species *Schizoporella hyalina*

and *Microporella ciliata* occur fossil, and might be remnants of a once universal fauna. Evidence shows that these forms have been able to withstand all changes of temperature and altered conditions of life, without either becoming extinct or undergoing modification so far as the hard parts are concerned.

Smittia. The genus appears to be cosmopolitan. It is found among the fossil tertiary deposits. It inhabits shallow and moderately deep water, the greatest recorded depth being 600 fath. (*S. smittiana*).

Smittia landsborovii appears to be characteristic of north and south temperate and cold seas, from shallow water to great depths. Fossil : Scottish glacial deposits.

The species *S. trispinosa* occurs in temperate and tropical zones, in shallow water and at great depths.

Porella. The genus is cosmopolitan, and is represented in the tertiary deposits. It occurs in shallow water chiefly, but does also occur at moderate depths.

These results, *as far as the Bryozoa are concerned,* seem to support Murray's theory on geographical distribution.

Each genus represented in the collection occurs fossil, and also occurs in the north and south temperate zones, as well as in the tropics ; in fact, most of the genera are cosmopolitan.

Many of the *species* are represented in the *tertiary deposits.* This shows that the changes of climate and altered conditions of life, have not affected their "tertiary" structure ; as many of these forms occur only in the two temperate zones, there is reason to believe that they have retained their common ancestral structure.

The fact of many of the species occurring in the

deep sea hardly supports Ortmann's theory, for many of them occur at very great depths only in the temperate regions; in the *tropics* they occur in *shallow* water. Their presence in the deep sea is, I think, the result of accident.

ANTHOMEDUSÆ.

MARGELIDÆ.

Hippocrene macloviana Haeckel, *Das System der Medusen*, p. 90. Peculiar to Falklands. Soledad Bay (Lesson). Stanley Harbour.

The genus (after allowing for Haeckel's weeding out of synonyms) is curious in its distribution, in that the species *H. macloviana* is the only representative in southern seas, and even this has, as yet, only been recorded from the Falkland Islands. The other members of this genus are found in the temperate and cold regions of the northern hemisphere as well as in the north tropical zone.

PORIFERA.

In the collection are two species of the genus *Sycon* :—

Sycon ciliatum Fleming. *Habitat:* Europe. New to Falklands.

Sycon ramsayi Lendenf. *Habitat:* Australia. New to Falklands.

One small specimen.

The genus is cosmopolitan in shallow to moderately deep water.

POLYCHÆTA.

NEREIDIFORMIA.

I. *Nereis eatoni* M'Intosh, *Challenger*, Vol. XII., p. 223. *Habitat:* East of South America. Fernando Noronhia, 25 fath. Marion Island,

69 fath. Kerguelen, 20 fath. Falklands, 5—10 fath.

II. *Nereis patagonica* M'Intosh, *Challenger*, Vol. XII., p. 228. *Habitat:* East of Strait of Magellan. New to Falklands.

III. *Nereis kerguelensis* Baird ?, *Challenger*, Vol. XII., p. 225. *Habitat:* Kerguelen. New to Falklands.

IV. *Nereis atlantica* M'Intosh, *Challenger*, Vol. XII., p. 219. *Habitat:* Cape Verde Islands. New to Falklands.

The genus is widely distributed in north and south temperate and tropical seas, from very shallow to very deep water (1,520 fath.).

The Polychæte species represented in the collection from the Falkland Islands appear to be peculiar to the southern temperate zone, although most of the genera are widely distributed in the north and south temperate and cold seas, as well as in the tropics.

V. *Lagisca magellanica* M'Intosh, *Challenger*, Vol. XII., p. 82. *Habitat:* Strait of Magellan, 175 fath. Kerguelen, 127 fath.

The genus appears to belong to the southern hemisphere, being widely distributed in that region, and in the tropics. It occurs also in the northern hemisphere, but is rare.

There were also present in the collection some fragmentary specimens belonging to the genera *Terebella* and *Cirratulus*, but they were too badly preserved for identification.

GEPHYREA.

Phascolosoma capsiforme Baird, *Proc. Zool. Soc.*, 1868, p. 83; Selenka's *Sipunculiden*, p. 27.

Numerous specimens of this species were found on roots of basket kelp after storms.

This species is peculiar to the Falkland Islands. The genus is cosmopolitan in shallow to very deep water.

MOLLUSCA.

Out of 45 species of Mollusca from Lively Island, Falklands, which Mr. Standen* has identified, 4 occur in the tropics as well as in the southern hemisphere; one ranges through the southern hemisphere, the tropics and the northern hemisphere, *Crepidula dilatata*, which extends all along the west coast of America from Patagonia to Alaska, and also occurs in Kamtschatka; 40 are found only in the southern hemisphere, 29 of which occur only in South America and the Strait of Magellan, whilst 5 are peculiar to the Falklands.

ECHINOIDEA.

Goniocidaris canaliculata Agassiz, *Revision of Echini*, p. 395. A single, young, somewhat damaged specimen.

This species has an extensive distribution. Southern oceans, 1,600-1,975 fath. Sandwich and Navigator Islands. Natal. Falklands, 5-12 fath.

It ranges along the southern extremities of all the southern continents and extends north of the equator to Japan.

G. canaliculata has a wider distribution than any other species of this genus, which is restricted, with this exception, to the southern hemisphere and to the tropics.

An interesting fact concerning this species is that it extends through the tropics to the northern hemisphere

* Melvill, J. C., and Standen, R., "Notes on a Collection of Marine Shells from Lively Island, Falklands" (*Journ. Conch.*, IX. 4).

along the western shores of the Pacific, and not along the *eastern* shores, as one would expect. This is still more interesting when we note that this species occurs at the southern extremities of America and Africa.

HOLOTHUROIDEA.

Cucumaria mendax Théel, *Challenger*, Vol. XIV., *Holothuroidea*, p. 65. The specimens are young and under average size. The species is restricted to the Falklands. The genus is cosmpolitan.

ASTEROIDEA.

I. *Asterias cunninghami* Perrier, *Arch. Zool. Expér.*, t. IV., p. 339. *Habitat:* Falklands and Strait of Magellan. Peculiar to this region.

The genus is cosmopolitan, from shallow water to 1,250 fath.

II. *Porania magellanica* Studer, *Challenger*, Vol. XXX., p. 363. Young specimen. *Habitat:* W. of Patagonia. Peculiar to the southern portion of South America.

The genus is widely distributed in north and south temperate and tropical seas, from 15 to 6,000 fath.

OPHIUROIDEA.

I. *Ophiothrix magnifica* Lyman, *Challenger*, Vol. V., *Ophiuroidea*, pp. 215, 216. *Proc. Boston Soc. Nat. Hist*, Vol. VII., 1860, p. 254. *Habitat:* Coast of Chili. Not previously recorded from Falklands. Peculiar to South America.

The genus is cosmopolitan, from very shallow to fairly deep water.

II. *Ophiomyxia vivipara* Studer, *Monatsb. K. Akad. Berlin*, 1876, p. 462 ; *Challenger*, Vol. V., *Ophiuroidea*, p. 245. *Habitat:* Cape of Good Hope, 150 fath. Kerguelen. S. W. of South America.

Strait of Magellan, 55-70 fath. Between Magellan and Falklands. Has not been recorded from the Falklands before.

Of the 4 species of this genus known :—

I. *O. viridpara* is only found in the southern hemisphere.

II. *O. australis* occurs in South Australia and south temperate region as well as the tropics.

III. *O. flaccida* occurs off Bahia and off Bermudas, *i.e.*, in south tropical and north temperate zone.

IV. *O. pentagona* occurs only in the northern hemisphere.

From the preceding one may conclude that, while the genus is widely distributed in temperate and tropical regions, the species, though overlapping each other to a certain extent, are somewhat limited in their distribution.

Of 6 representatives of the Echinoderms in the collection, 3 species are peculiar to South America, 2 of which are found in the Strait of Magellan, as well as the Falklands ; one is peculiar to the Falkland Islands. Two species are apparently distributed over the southern hemisphere, one of them extending beyond the Equator to the north temperate region.

BRACHYURA.

a) CATOMETOPA.

PINNOTHERIDÆ.

Halicarcinus planatus White, *Ann. Mag. Nat. Hist*, Vol. XVIII. 1846, p. 178, is widely distributed over the Antarctic region, and is said to be the only Brachyurous Decapod proper to that wide area of distribution. Stebbing, *Crustacea*,

(*b*) CYCLOMETOPA.

CANCRINEA.

CANCRIDÆ.

Xantho crenatus Milne Edwards, *Crustacea*, Vol. I., p. 396. Coasts of Peru. New to Falklands.

MACRURA.

ANOMURA.

(*a*) LITHODEA.

LITHODIDÆ.

Paralomis verrucosus Dana, *U.S. Expl. Exped., XIII., Crust., pt. 1., p. 428.* Falklands. Common in E. portion of Strait of Magellan, not further W. than C. Negro. Genus taken south and north of tropics, but not within tropics.

(*b*) PAGURODEA.

PAGURIDÆ.

Eupagurus comptus White. Peculiar to Falklands, and Fuegian region.

ISOPODA.

IDOTEIDÆ.

Edotia tuberculata Guérin-Méneville, *Iconographie du Règne Animal de G. Cuvier, T. III., Crust., p. 34. Habitat:* Confined to Strait of Magellan and the Falklands.

SPHÆROMIDÆ.

Sphœroma gigas Leach, *Dict. Sci. Nat.*, t. 12, p. 346 ; Milne-Edwards, *Crustacea*, Vol. III., p. 205. *Habitat:* Strait of Magellan. Falklands. Australia. New Zealand. Kerguelen. Aucklands (Southern Hemisphere).

AMPHIPODA.

Orchestia chilensis Milne-Edwards, *Crustacea*,

Vol. III., p. 18. *Habitat:* Mediterranean and coasts of Chili; not previously recorded from Falklands.

Of the seven species of Crustacea in this collection of common shore fauna, one is common to the northern and southern hemispheres (*Orchestia chilensis*), two are distributed over the temperate portion of the southern hemisphere, and four are peculiar to the neighbourhood of the Falklands.

Paralomis. The genus occurs north and south of the tropics but not within the tropics; of 3 species, 2 occur in moderately deep to deep water, 310-600 fath.; the third, *P. verrucosus*, appears to be a shallow-water form.

Halicarcinus. The genus appears to be widely and universally distributed over the southern portions of the three great continents in the southern hemisphere.

Xantho. Genus cosmopolitan, and fossil.

Eupagurus. The genus is distributed in north and south temperate regions as well as the tropics, but the species of this genus appear to be very limited in their distribution. The depths vary from 0 to 700 fathoms.

Idotia. The distribution of this genus appears to be somewhat doubtful. A species, *I. bicuspida*, occurs in the Arctic seas. I have been unable to ascertain if the genus is represented in the tropics.

Sphæroma. The genus appears to be almost universally distributed over the temperate and tropical areas, but the species appear to have a very limited distribution.

Orchestia. The genus appears to be cosmopolitan in temperate and tropical littoral waters; the species of this genus, like those of other genera in this collection, are limited in their distribution.

Regarding the seven *genera* represented in this collection: three (*Eupagurus*, *Sphæroma*, and *Orchestia*) are

widely distributed in temperate and tropical waters; one (*Xantho*) is cosmopolitan; one (*Paralomis*) has been recorded from the north and south temperate regions, but not from the tropics. One (*Halicarcinus*) is confined to the southern hemisphere; and the distribution of one (*Edotia*) is doubtful.

The distribution of the genus *Paralomis* in northern and southern temperate seas, but not in the tropics, cannot be said to support Murray's view, for I do not think this genus has been recorded as occurring fossil. The tendency of this genus to retire into deep water might be said to support Ortmann's view, but there is not much evidence to turn the balance in favour of either one or the other.

There appears to be no evidence among the representatives of Crustacea in this collection of a passage from one temperate zone to the other, along the west coasts of America or Africa.

TUNICATA.

ASCIDIÆ SIMPLICES.

Boltenia legumen Lesson, *Centurie Zoologique* (1830), p. 149; *Challenger*, Vol. VI., *Tunicata*, p. 88. *Habitat:* Falklands, and southern extremity of South America.

The genus appears to be specially characteristic of north and south temperate seas, but has not, I think, been recorded from the tropics.

Molgula gregaria Lesson = *Cynthia gregaria*, *Cent. Zoolog.*, p. 157; *Challenger*, Vol. VI., *Tunicata*, p. 73. *Habitat:* Limited to Strait of Magellan and the Falkland Islands. It appears to have been found only in shallow water.

The genus appears to be almost universally distributed over the temperate portion of the southern hemisphere.

Comparison of the common shore fauna of the Falkland Islands with that of Britain.

It is interesting to note that there is a certain resemblance between these two faunas, but it is more clearly marked in some groups than in others. This may be due, to a certain extent, to the great or small number of species of the groups represented in the collection.

Of the 16 species of Bryozoa represented, 6 (of which two are cosmopolitan) are also found on our shores.

Of species belonging to other groups, one (*Sycon ciliatum*) is British.

All the genera (13) of Bryozoa in the collection are represented in the British fauna; of these, 8 are cosmopolitan, the remainder are found only in temperate and tropical waters.

Of the 22 genera belonging to other groups, 15 are British, 2 are restricted to the southern hemisphere, 4 are found in the southern hemisphere, tropics and northern hemisphere (Japan); the distribution of one (*Edotia*) is doubtful.

Of the 24 species, exclusive of the Bryozoa, occurring in this collection, 19 have been found in the southern hemisphere only; of these, 7 are more or less uniformly distributed over the temperate portion, and 12 (three of which are peculiar to the Falkland Islands) have been recorded from and about the southern portion of South America. Three have been recorded from north and south temperate regions only; one from north and south temperate regions and the tropics; one from tropics and southern hemisphere only.

The evidence gained from a study of the distribution of the common shore fauna of the Falkland Islands, points to a near and close relationship, among the majority of forms, between the faunas of the temperate portions of the three great continents, including the islands in temperate latitudes of the southern hemisphere.

Distribution of species, exclusive of Bryozoa, in the Collection.

	N. & S. temperate.	N. & S. temp. + Tropics.	Temperate. Southern Hemisphere.	Temperate. South America.	Falklands.	Tropics and Southern Hemisphere.
Coelenterata.					*Hippocrene macloviana*	
Porifera.	*Sycon ciliata*		*Sycon ramsayi*			
Vermes. Polychæta.			*Nereis eatoni* *„ kerguelensis* *Lagisca magellanica*	*Nereis patagonica*		*Nereis atlantica*
Vermes. Gephyrea.					*Phascolosoma capsiformis*	
Echinoderma.		*Goniocidaris canaliculata*	*Ophiomyxia vivipara*	*Asterias cunninghami* *Porania magellanica* *Ophiothrix magnifica*	*Cucumaria mendax*	
Crustacea.	*Orchestia chilensis*		*Halicarcinus planatus* *Sphaeroma gigas*	*Xantho crenatus* *Paralomis verrucosus* *Eupagurus comptus* *Edotia tuberculata*		
Tunicata.			*Boltenia legumen*	*Molgula gregaria*		
Total 24.	2	1	8	9	3	1

EXPLANATION OF PLATE 5.

Fig. 1. *Lepralia adpressa*, var. *Busk. Group of zoœcia, magnified about 260 diam.*
k, knobbed cell.
a, knobs. Characteristic of British species.
s, spatulate avicularium.
p, pores round margin between furrows.

Fig. 2. *Single cell, magnified about 380 diam.*
C. A., circular avicularium.
Ch.m., chitinous mandible.

Fig. 3. *Avicularia, magnified about 380 diam.*
a and b are avicularia of the ordinary beak-like type.
c and d are circular avicularia, showing mandible in two different positions.

Fig. 4. *Porella tridentata. Portion of colony showing disposition of zoœcia, magnified about 260 diam.*
a, spatulate avicularium,
b, lateral raised collar, meeting behind in a depression.
c, median denticle.
d, lateral denticles.
RA, median avicularium with rounded mandible.

Fig. 5. *Single cell, magnified about 380 diam.*
a, spatulate avicularium.
b, median avicularium with rounded mandible.
c, median denticle.
d, two lateral denticles.
Ov, vicell.

PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 5th, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Dr. C. H. LEES gave an account of *Zeeman's* further researches on the effect of a magnetic field on light, and explained the theory of the production of triplets in directions perpendicular to the lines of the field.

Mr. F. J. FARADAY suggested that, in view of the enormous importance of the question of the duration of the gold supply, considered from an economic standpoint in connection with the increasing legislative tendency to base all valuations and all contracts for long periods ahead on gold, the Council might usefully elicit from Professor Suess, of Vienna, an honorary member of the Society, and the highest living geological authority on the physical formation of the crust of the earth and on the deposits of the precious metals, an expression of opinion on the character of the Klondike deposits and also on the South African deposits according to the latest evidence yielded by the development of mining. In Mr. Faraday's opinion, the question had a scientific importance in economics equal to that of the duration of the coal supply.

Several members of Council spoke on the subject, expressing a fear lest the introduction of a practice of officially soliciting

papers might have a deterrent effect upon the supply, which had hitherto been voluntary, and desiring that Mr. Faraday should approach Professor Suess independently on the subject.

The following paper was read :—

"A mechanical device for the solution of problems in refraction and polarization." By THOMAS THORP.

In determining the relation existing between the angles of incidence and refraction, the experimental apparatus usually employed, or at least the simplest form of it, has the characteristics shown on *Fig. 1*, in which AB

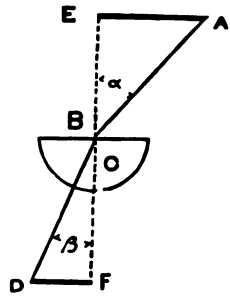

Fig. 1.

is the direction of a ray of light in one medium, say air, incident upon the surface of a denser medium C, say water, contained in a semi-cylindrical vessel, at B, where it is refracted, and then proceeds to D.

By making AB = BD = 1 and putting α the angle of incidence and β that of refraction, the lines AE and DF are the sines of α and β respectively.

Now these sines are found to bear the same ratio to each other at all angles of the incident ray from the vertical,—different media giving different ratios, which are known as refractive indices. When the angle of incidence is 90° that of refraction will necessarily be less than 90°, and is termed the critical angle.

From experiments made with this form of apparatus, however, very little, if any, insight can be obtained into the actual working of the law of refraction as determined by it. Recourse must therefore be had to other methods.

In *Fig. 2*, let a ray of light AB be incident upon the surface of C, as before, but at one extremity of the diameter of the semi-cylindrical vessel, instead of at the centre, and let BD be the

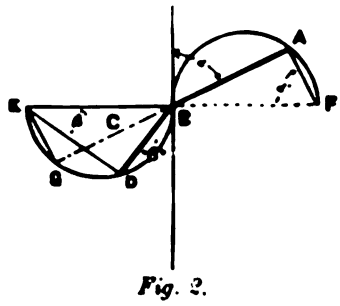

Fig. 2.

refracted ray. Describe a semi-circle BAF having its diameter BF = BE = 1 and cutting the ray AB in A. Join AF and DE and produce AB to G, joining EG. Now as AF and DE are normal to AB and BD respectively and EB = BF; AB and BD are the sines of the angles α' and β' respectively. But α' is equal to the angle of incidence α and β' to β, therefore AB (= BG) and BD are also the sines of the angles of incidence and refraction.

Although incidentally interesting it will be readily seen from the figure that the refractive index of a medium is simply the time that light takes to travel a distance in the medium which it travels in unit time in air, or more correctly in a vacuum.

It will now be quite evident that if an instrument be constructed with BG and BD constant and their intersection with their normals through E kept all in the semi-circle, the phenomenon of refraction will be exhibited mechanically.

Some time ago I designed such an instrument which fulfilled to some extent these conditions. The principle is shown in *Fig. 3*, in which AB is made equal to the refractive

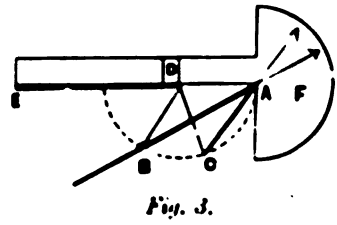

Fig. 3.

index, AC being unity and constant, B being movable as desired. At D is a slide guiding two equal cords of length EA, secured at E, C and B. The rods AB and AC terminate in pointers on a protractor F.

By moving the slide D towards or away from A the varying angles of incidence and refraction are shown by the pointers.

Another construction which lends itself to instrumental requirements more perfectly, however, is shown in *Fig. 4*, in which BG is the mean proportional between BD and BC.

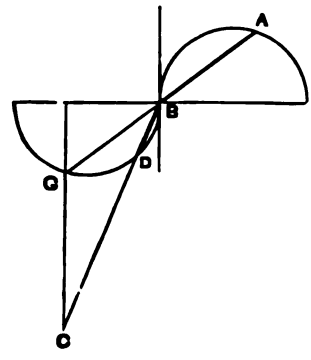

Fig. 4.

In my latest instrument, of which *Fig. 5* is a diagrammatic representation, the above construction is utilised.

A is a slide capable of being moved along the diameter of

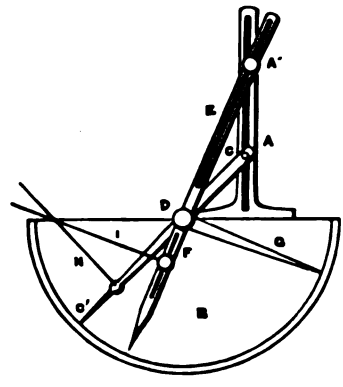

Fig. 5.

the protractor B. C is a rod of constant length representing the incident ray and passing through the centre, D, of the protractor and terminating in a pointer C'. At its other extremity is a projection entering a slot in the slide A. E is a rod divided into parts in terms of C, representing the refracted ray produced, and having the movable projection A' capable of being clamped in any desired position on E. G is a pointer normal to F which represents the refracted ray. H and I are the normals to C' and F, the latter being movable. These normals can be adjusted to intersect on the diameter of the protractor, and serve to demonstrate that the refractive index of a substance is simply a measure of the retardation in the velocity of the light in the medium.

The polarizing angle is shown when the normal G and the incident angle pointers are in the same position on the protractor, but on opposite quadrants.

The instrument is particularly adapted for solving approximately numerical problems in refraction, as will be seen from the following examples.

1. If the refractive index of a medium is 1·67, the instrument gives the critical-angle to be 36¾°, and angle of polarization 59°.

2. If the polarizing angle of a medium is 60°, the instrument gives its refractive index 1·73.

3. The inner prism of a direct vision spectroscope is required to be of angle 90° with a refractive index of 1·96, that of the outer ones being 1·52, required the angles of the outer prisms.

For refraction at the adjacent surfaces put

$$\frac{1\cdot96}{1\cdot52} = 1\cdot29.$$

Set the movable projection to 1·29 and bring refracted-ray pointer to 45°, when the incident-ray pointer shows 66° or a difference of 21°: therefore refraction at first surface must be through this arc (21°).

Now set the movable projection to 1·52 and bring pointer to show a difference of 21°, we find 31·9° and 52·9°.

$$\left.\begin{aligned} 90^\circ - 52\cdot9^\circ &= 37\cdot1^\circ \text{ first angle} \\ 45^\circ + 52\cdot9^\circ &= 97\cdot9^\circ \text{ second } \,, \\ 45^\circ &= 45^\circ \text{ third } \,, \end{aligned}\right\}$$

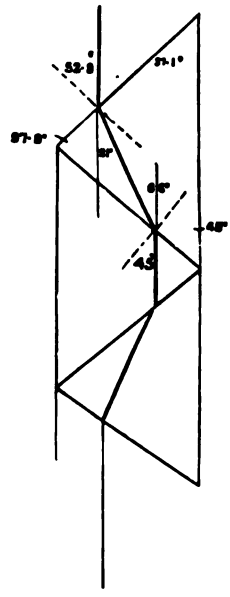

Fig. 6.

Numerous examples of its use can be given, but the foregoing will serve to show the use to which the instrument can be put, and although its indications will not suffice where great accuracy is required still the results are very satisfactory, and in any case I cannot but think that it will prove of some educational value in affording a better insight into the principles underlying refraction than can be obtained from the usual geometrical constructions.

Professor Lamb mentioned Sir George Airey's model illustrating the refraction of light, and Dr. Lees and Mr. C. L. Barnes took part in the discussion of the instrument and the geometrical construction which it is designed to illustrate.

General Meeting, October 19th, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

Mr. Wilfred B. Faraday, LL.B., Ramsay Lodge, Burnage Lane, Levenshulme, Mr. William Thomas Rothwell, Heath Brewery, Newton Heath, and Mr. Charles Henry Wyatt, School Board Offices, Manchester, were elected ordinary members of the Society.

Ordinary Meeting, October 19th, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The death of Mr. James Heywood, F.R.S., who was the oldest member of the Society, having been elected in 1833, was announced, and on the motion of the President, seconded by Professor Osborne Reynolds, a resolution expressing sympathy and condolence with the members of the family was carried unanimously.

Professor WEISS exhibited some flowering specimens of the plant called Dog's Mercury, collected by Mr. F. J. George, of Chorley. The Dog's Mercury usually flowers in the early spring, but the plant from which the shoots exhibited were collected has been observed by Mr. George for thirteen successive seasons to flower in the autumn. Sir Joseph Hooker, to whom some of these shoots have been sent, was of the opinion that it might be regarded as a special form with this autumn-flowering character.

The PRESIDENT communicated a paper from Mr. PETER

CAMERON, entitled "**Notes on a Collection of Hymenoptera from Greymouth, New Zealand, with descriptions of New Species.**"

This paper is printed in full in the *Memoirs*.

The PRESIDENT also exhibited, on behalf of Mr. HENRY HYDE, specimens of *Sisymbrium strictissimum* L. from the banks of the river Mersey, near Stretford.

Mr. HYDE wrote: "The first time I met *S. strictissimum* was in June of last year, on the banks of the Mersey at Stretford. I went there again this year and found it in three other places, one of which was at least a mile from the others in the direction of Northenden. Three out of the four specimens found were in fruit. *Hieracium amplexicaule* has been growing on the canal-bank at Stretford for years. It is fairly abundant on the buttress of the bridge that spans the Mersey, and looks very beautiful when in full flower.

"I found *Vicia orobus* in June of this year on a road parallel with the Bala road at Dolgelly. I found the *Carduus* on the railway embankment near to Patricroft Station."

Ordinary Meeting, November 2nd, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Professor W. BOYD DAWKINS, F.R.S., exhibited a section of a spruce trunk which had been completely hollowed by the mycelium of a polysporous fungus. The resinous pine-knots, however, are left entire, radiating from the centre of the trunk. He also pointed out that similar pine-knots had been found in the inter-glacial deposit at Darnten, and had been examined by him in the Museum at Basle. These pine-knots had been considered by Professors Rütimeyer and Schwendauer to be the remains of old basket-work or wattle-work and thus to prove the

existence of inter-glacial man. They are, however, merely the result of the decay of the wood and are not artificial.

Professor DAWKINS also showed under the microscope a section of Fardel coal, showing a resinous stem or knot from the original carboniferous plant, while the rest had gone to form the black substance of the coal.

Professor Weiss made some remarks on Professor Dawkins' exhibit, attributing the destructive action to the fungus *Trametes pini*, and explained the manner in which the fungus was able to reach and destroy the centre of the tree.

Professor WEISS then exhibited a specimen of *Plowrightia morbosa*, the black-knot, on a branch of the cherry, collected in Canada, where it has been the cause of considerable destruction of cherry trees.

Professor WEISS also exhibited fructifications of *Peziza æruginosa*, the green-rot of the oak which he had quite recently collected at New Abbey, near Dumfries.

In the discussion which followed, and which turned mainly upon the colouring-matter of the wood-fungi, the President, Professor Reynolds, Dr. G. H. Bailey, Dr. F. H. Bowman, and Mr. Stirrup took part. Professor Dixon referred to a paper read at the British Association Meeting, at Montreal, in 1884.

Professor H. B. DIXON, F.R.S., described some experiments in obtaining photographs of explosion flames, the first attempts having been made abroad, and also some later attempts of his own. Slides, showing the course of the explosion flames in tubes, were exhibited by the electric lantern, and the character of the explosion as indicated by the photographs was remarked upon.

Professor Reynolds, Professor Lamb, Dr. C. H. Lees, and Mr. Gwyther took part in the discussion upon the exhibition.

Ordinary Meeting, November 16th, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. S. JOYCE exhibited a pocket form of volt-meter of the permanent-magnet class. It is contained in an old-fashioned watch-case, the first example having been made by Mr. Joyce in 1885. The present instrument is wound to read to three volts, a reading much required in a cell-tester for users of secondary batteries. In order to make the case quite smooth outside, the terminals are formed of two spring-chucks contained inside the instrument, and capable of gripping any wire from No. 24 to No. 18, B.W.G. Instruments have been made reading to 120 volts total.

The PRESIDENT communicated a paper by Mr. PETER CAMERON, entitled "**Descriptions of two New Species of Mutilla from South Africa.**"

This paper is printed in full in the *Memoirs*.

The specimens were exhibited at the meeting.

General Meeting, November 30th, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

Mr. Henry Wybrow Freston, Parkfield, Prestwich, and Mr. Charles Edmund Stromeyer, Assoc. Memb. Inst. C.E., Chief Engineer, Steam Users Association, Manchester, were elected ordinary members.

Ordinary Meeting, November 30th, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT announced that the Council had awarded the Wilde Gold Medal of the Society for 1898 to Sir Joseph Dalton Hooker, C.B., G.C.S.I., F.R.S., in recognition of his eminent services to all branches of Botanical Science; and an original Dalton Medal of the Society struck in 1864, for 1898 to Dr. Edward Schunck, F.R.S., for his remarkable series of researches on the natural colouring matters; and also the Premium under the Wilde Deed of Trust for 1898 to Mr. John Butterworth, of Shaw, for his paper printed in the last volume of the *Manchester Memoirs* "On some further investigations of fossil seeds of the genus *Lagenostoma* Williamson." The date of the meeting for the presentation of the medals and the delivery of the Wilde lecture would be announced at a later date.

Professor HORACE LAMB, F.R.S., read a paper "**On waves in a medium having a periodic discontinuity of structure.**"

This paper is printed in full in the *Memoirs*.

Professor Reynolds, Mr. Tristram and Mr. Barnes took part in the discussion.

Ordinary Meeting, December 14th, 1897.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Professor OSBORNE REYNOLDS, F.R.S., and Mr. WILLIAM HENRY MOORBY, B.Sc., gave an account of the methods, appliances and limits of error in the experimental determination of the work expended in raising the temperature of ice-cold water to that of boiling water, which they had used in the investigation "**On the Mechanical Equivalent of Heat,**" which constituted the Bakerian Lecture before the Royal Society in 1897; and they also shewed lantern illustrations of the engines and apparatus designed for the purpose.

An abstract of this paper will be printed in the *Memoirs*.

The PRESIDENT read a paper, entitled:—"**Further investigations into the Molluscan Fauna of the Arabian Sea and the Persian Gulf.**"

This paper will be printed in full in the *Memoirs*.

Mr. CHARLES H. LEES, D.Sc., read a paper, entitled:—"**A Method of Determining the Thermal Conductivities of Salts.**"

This paper will be printed in full in the *Memoirs*.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, October 11th, 1897.

MARK STIRRUP, F.G.S., President of the Section, in the Chair.

The PRESIDENT gave an address on Finland, recently visited by members of the Geological Congress, illustrated by maps and rock specimens. The geological structure of pre-Cambrian rocks and the present glaciated land-surface were described; the eskers of sand and gravel now used in many instances for lines of road, the coast islands, forests of coniferous trees and the innumerable lakes all connected by canals forming a network of waterways over the whole country. Traces of gold have been found in the northern parts.

Mr. COSMO MELVILL described and exhibited specimens of a plant just reported as a native of Great Britain:—namely, *Stachys alpina* L. found by Mr. Cedric Bucknill in a coppice on a hill near Wootton-under-Edge, Gloucestershire.

Mr. HENRY HYDE exhibited specimens of *Sisymbrium strictissimum* L., a plant new to England, also of *Vicia orobus* and *Hieracium amplexicaule*. See *Proceedings of the Society*, p. viii.

A paper by Mr. PETER CAMERON, F.E.S., illustrated by specimens, was submitted, entitled:—"**A collection of Hymenoptera from Greymouth, New Zealand, with a catalogue of the recorded New Zealand species.**"

This paper is printed in full in the *Memoirs*.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, November 8th, 1897.

MARK STIRRUP, F.G.S., President of the Section, in the Chair.

Mr. J. COSMO MELVILL exhibited a large collection of Alpine plants collected by himself during June and July, 1897, in the Ampezzo Thal, S. Tyrol, Austria; mainly on the mountains round Schluderbach, Landro, and Cortina d'Ampezzo —all of the magnesian limestone called Dolomite. The mountains range in height from 7,500 to 12,900 feet, being capped by the Drei Zinnen, Monte Cristallo, Dürrenstein, and Croda Rossa. Of these the Monte Cristallo, with its glaciers, is the most conspicuous, and seems to dominate the entire valley. The Croda Rossa is almost inaccessible, and is one of the finest of the Dolomite mountains for variety of colours, the red rock contrasting with the snowfield below. It has thus acquired the local name of the Mount of the Crucifixion.

Between 400 and 500 species of Phanerogams and Ferns were gathered, the most striking and local being the *Potentilla caulescens*, *Phyteuma comosum*, *Pæderota bonarota*, *Sesleria sphærocephela*, *Artemisia nitida* and others, which specially affect crevices in the living Dolomite. The detritus and stony beds of the R. Rienz ere it flowed into the Dürren-see, afforded many interesting plants, such as *Thlaspi rotundifolium*, *Poa minor*, *P. laxa*, *Cerastium carinthiacum*, *Papaver alpinum*, *Scrophularia hoppei*, etc., and the precipitous woods of the Platz Wiesen, Eduardfelsen, Schwartzkofel and the Monte Piano, abundance of *Anemone trifolia*, *Rhododendron chamæcistus*, *R. hirsutum*, *Sorbus chamæmespilus*, *Polygala chamæbuxus*, *Atragene alpina* and *Crepis incarnata*, while higher up occurred the curious *Ranunculus hybridus*, *R. pyrenæus*, three species of *Soldanella*, of which *S. minima* is the most elegant,

Horminum pyrenaicum, *Gentiana* seven or eight species, *verna* being the most plentiful. Two species of *Daphne* occurred, one, *D. cneorum*, at 5,000 to 7,000 feet, the other, *D. striata*, more alpine. Between Eduardfelsen and the Monte Cristallo Glacier is a narrow gorge flanked on each side by vertical precipitous rocks, while the stony bed of a mountain stream, issuing from the glacier, is between. Beyond this is the most perfect fernery ever beheld. The ground is swampy, with a small trickling stream, but the growth of *Cystopteris montana*, *Polystichum lonchitis*, *Polypodium robertianum*, and *Asplenium viride* is marvellous. At a similar place by the Sigmund's Brunnen, off another spur of the Monte Cristallo, was found *Cystopteris regia* Presl.

Above 7,500 feet the plants assume a thoroughly alpine character. Edelweiss is more plentiful than in Switzerland. *Primula longiflora*, *Saxifraga androsacea*, *S. sedoides*, *Arnica montana*, *Achillea moschata* and *clavenna*, *Sempervivum dolomiticum*, *Potentilla minima*, *aurea*, *nitida* (with pink flowers), being amongst the more noticeable, as well as many *Caryophyllacea*.

In the alpine meadows, near Cortina, below the Tre Croci Pass, and at the Platz Wiesen, below the Durrenstein, occurred *Gentiana utriculosa*, *Cineraria alpestris*, *Cirsium erisithales*, *Orobus luteus*, *Nigritella angustifolia*, *Festuca pumila*, *F. spadicea*, *Myosotis alpestris*, *Paradisea liliastrum*, known commonly as St. Bruno's Lily, *Scorzonera aristata*, *Arnica montana*, *Crepis alpestris*, *Laserpitium latifolium* and very many others.

In the (comparatively speaking) low land (4,700 ft.) by the Schluderbach Hotel occurred *Primula farinosa*, *Gentiana verna*, *Pyrola rotundifolia*, *uniflora*, *Aposeris foetida*, *Daphne cneorum*, *Bellidiastrum michelii*, *Biscutella saxatilis* most abundant, *Moehringia muscosa*, *polygonoides*, *Dianthus carthusianorum*, the local *Laserpitium peucedanoides*, and several *Hieracia*. The chief trees were *Pinus mughus*, *P. cembra* and the Spruce Fir. Dwarf Birches and many kinds of Alpine Willow were found up to 8,500 ft., most of the latter either by the Sigmund's Brunnen, near Schluderbach, or on the ascent of the Toblinger Riedel, on the way to those three most wonderful peaks, standing alone, castellated, bare, and precipitous, the Drei Zinnen.

A few interesting Lepidoptera, Coleoptera, and other insects were noticed, including *Pieris callidice*, which affected mountain tops, in company with a few *Erebiæ*. Only seven species of Land Mollusca were seen, of them the alpine form of *Arianta arbustorum* was the most frequent.

Mr. THOMAS ROGERS exhibited a small collection of *Bryozoa*, from South Australia, and described the work among this group of animals of Mr. Waters, a former resident in Manchester, and a member of the Society.

Mr. J. F. ALLEN exhibited specimens of Chromium and an alloy of manganese and tin, requiring for their production the intense heat of the electrolytic furnace; also bars of various sections of manganese bronze obtained by Dick's extrusion process, a ram forcing the metal under pressure through openings of any desired section. Bars and rails of any length can thus be obtained superior to those of the rolling process. The sections are fibrous and of much higher tensile strength.

Ordinary Meeting, January 11th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. R. F. GWYTHER read a paper "**On a General Method in determining the Form of the Velocity-Potential of Fluid Motion in Two Dimensions across a Channel with Straight Sides.**"

Professor Lamb, F.R.S., and Dr. C. H. Lees took part in the discussion which followed.

The paper will be printed in full in the *Memoirs*.

General Meeting, January 25th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President in the Chair.

Mr. Louis Schwabe, Hart Hill, Eccles Old Road, Pendleton, was elected an ordinary member of the Society.

Ordinary Meeting, January 25th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT referred to the loss sustained by the Society through the death of Mr. Thomas Ashton, who, since the death of Mr. James Heywood, was the oldest member of the Society, having been elected in 1837.

Mr. J. J. ASHWORTH called attention to a paper by Mr. J. Smith (brother of the late Dr. Angus Smith) in Vol. XXI. of the Society's *Memoirs* (1859) "on the origin of colours and the theory of light," in which is given a complete description of the colour-phenomena seen when a black and white disc is rapidly rotated. As the phenomena have been to some extent re-discovered during the past few years, and have attracted considerable interest, Mr. Ashworth thought it advisable to direct attention to a paper, which appeared to have been forgotten, in which the subject is treated with great thoroughness.

The PRESIDENT exhibited specimens of *Ægilops*, *Triticum*, and *Agropyrum* from his herbarium, as bearing upon the subject of an enquiry made at a recent meeting of the Society as to the origin of wheat, *Triticum vulgare* Vill. being not supposed to have ever been found in a truly wild condition. Mr. Melvill particularly pointed out *Ægilops ovata* L., having a distribution over the Mediterranean region of Europe from Portugal to Crete, and likewise, according to Boissier (*Flora Orientalis*, vol. V. p. 674), extending to Persia, Egypt, and the Caucasus, North Africa, and the Canary Islands. It does not, however, find a place in the flora of India, or further East. M. Fabre, of Agde, announced some fifty or more years ago that this grass, when cultivated, became wheat. In a condition of nature, *Æ. ovata* is more fragile, and the glumes and paleæ possess a larger

number of awns than in the somewhat muticous or short awned wheat. We hear that the experiments, carried out under the supervision of distinguished botanists and agriculturists, both in England and on the Continent, confirmed M. Fabre's discovery, and yet now the *Ægilops* is not so much considered the parent of wheat as a wild *Triticum* of Asia Minor and Mesopotamia, viz.: *Triticum monococcum* L., which Boissier (*Flora Orientalis*, vol. V. p. 673) also indicates from Greece. It must be confessed that, at first sight, this wheat grass has more the appearance of the cultivated form, with the more regular spike, though longer awned than the cultivated *T. vulgare*. Another cereal, known as *T. polonicum*, has, however, long awns; so, indeed, has *T. durum*, with very broad leaves and elongate, hard grains.

In the just published *Flora of India* (vol. VII., p. 367), Sir J. D. Hooker quotes Murray's article in Watts' *Dictionary of the Economic Products of India*, amongst other references, as to *T. monococcum* L. being the origin of all wheat cultivated in India. Ten varieties are signalised as being cultivated in that country, including *T. spelta* L. and *T. compositum* L. This last has been popularly known as Mummy Wheat, but there can be no doubt that no seeds found in the Egyptian tombs have germinated.

The chief point of difference between the genera *Triticum* and *Ægilops* (united in Bentham and Hooker's *Genera Plantarum*, vol. III., p. 1204) consists in the glumes of the latter never being keeled or carinate. *T. monococcum* in its wild state bears a certain superficial resemblance to *Hordeum* or Barley; the difference between the two genera is as follows:—

Triticum L.	*Hordeum* L.
Spikelets with two or more flowers, all perfect.	Spikelets in threes, the side ones usually barren, none with more than one perfect flower.

M. Alphonse de Candolle, in his *Origin of Cultivated Plants* (pp. 354-370), gives an interesting dissertation on the origin of wheat, and has collated a number of facts well worth perusal, the upshot being that he considers all wheats emanated from a

common source, distinguishing wheat from other cereals as that grain which, when ripened, detaches itself from the husk readily. He subdivides this species into

(*a*) Common Wheat. *Triticum vulgare* Vill.
(*b*) Turgid Wheat. *T. turgidum* and *compositum* L.
(*c*) Hard Wheat. *T. durum* Desf.
(*d*) Polish Wheat. *T. polonicum* L.

He points out that Alsfeld (*Botan. Zeitung*, 1865), having examined carefully (*a*), (*b*) and (*c*) growing together, was able to give their common origin. He considers *T. monococcum* L. more allied to the Spelt, *T. Spelta* L., these being wheats whose seeds when ripe are closely contained in the husk, and not easily detachable from it. As regards Mummy Wheat, De Candolle points out that no grains found in the Egyptian tombs have ever been known to germinate, and that it is a popular fallacy to suppose that they have done so.

The PRESIDENT afterwards communicated a paper by Mr. PETER CAMERON, entitled "**Hymenoptera Orientalia, or Contributions to a knowledge of the Hymenoptera of the Oriental Zoological Region,**" Part VII.

The paper will be printed in full in the *Memoirs*.

General Meeting, February 8th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

Rev. Arthur Taylor, M.A. (Oxon), Manchester Grammar School, was elected an ordinary member of the Society.

Ordinary Meeting, February 8th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT nominated Mr. Frank Southern and Mr. Thomas Thorp to be the auditors of the Society's accounts for the present session.

Mr. A. BROTHERS exhibited and described the latest form of Mr. F. E. Ives' photo-chromoscope, called the "krōmskōp." Stereoscopic photographs were shown in which the various objects, when viewed through the arrangement of red, blue, and green glasses, were seen in all the colours of nature—groups of flowers, landscapes, &c., being thus realistically reproduced.

Messrs. R. H. JONES, B.Sc., and J. BOWER, B.Sc., read a paper (communicated by Professor Dixon, F.R.S.) "**On the Instantaneous Pressures produced in Explosion Waves,**" illustrated by diagrams and lantern slides, a discussion followed in which Professors Dixon, Lamb, and Reynolds, Dr. C. H. Lees, and Mr. R. F. Gwyther participated.

The paper will be printed in full in the *Memoirs*.

Ordinary Meeting, February 22nd, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT announced that Professor Michael Foster would deliver the Wilde Lecture before the Society on March 29th.

The PRESIDENT exhibited an interesting series of distortions and hyperstrophical deformities of *Planorbis spirorbis* L., found by Mr. Arthur Stubbs at Black Rock, Tenby. These distortions included (1) evolute whorls, (2) various forms of carination, (3) sinistral turbinate spirals, and (4) dextral turbinate spirals. The causes for such malformations are at present practically unknown, but may be traced to the obstructions to the active but tender-shelled mollusc caused by duckweed and confervæ.

A discussion on the subject of inversion of vision was afterwards participated in by several members.

Ordinary Meeting, March 8th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT announced that the title of the Wilde Lecture, to be delivered by Professor Michael Foster, would be "On the Physical Basis of Psychical Events."

Mr. T. THORP exhibited some celluloid films taken from Rowland's gratings of 14,438 lines to the inch. By making use of the refractive properties of prisms, the first and second orders of spectra are obtained by direct vision. The dispersion is such as to easily separate the two D lines, and is practically normal.

After demonstrating the action of the grating as applied to a prism, Mr. Thorp suggested a simple form of spectroscope on this principle, which could be used for solar prominence observations.

Mr. F. J. FARADAY opened a discussion as to the relative merits of cane and beet sugar, and whether the effect of the sugar bounties is to substitute an inferior for a superior sugar. Several members took part in the discussion, the prevailing opinion being that, while no difference can be detected chemically or physically between the two sugars, cane sugar seems to be distinctly superior in its sweetening and preserving qualities.

Professor H. LAMB, F.R.S., read a paper "**On the Velocity of Sound in a Tube, as affected by the Elasticity of the Walls.**"

The paper will be printed in full in the *Memoirs*.

Ordinary Meeting, March 22nd, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT read a description and exhibited two specimens of *Strombus* (*conomurex*) *belutschiensis*, just discovered by Mr. F. W. Townsend off the Mekran Coast of Beluchistan.

The description is printed as an Appendix to Mr. Melvill's paper on "Further investigations into the Molluscan Fauna of the Arabian Sea and the Persian Gulf," in the *Memoirs*.

Professor S. J. HICKSON, F.R.S., communicated a paper by Miss E. M. PRATT, entitled "**Contributions to our knowledge of the Marine Fauna of the Falkland Islands.**"

The paper will be printed in full in the *Memoirs*.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, December 6th, 1897.

MARK STIRRUP, F.G.S., President of the Section, in the Chair.

Mr. John Butterworth, F.R.M.S., Shaw, near Oldham, was elected an Associate of the Section.

Mr. J. C. MELVILL exhibited forty-three species of Marine Mollusca, shortly to be described by him. Twenty-eight were from the Mekran Coast and Persian Gulf, collected by Mr. F. W. Townsend, and are described in the paper entitled "Further Investigations into the Molluscan Fauna of the Arabian Sea," published in the *Memoirs* of the Society. The remaining fifteen were dredged by Captain E. R. Shopland in the vicinity of Aden, and include a most beautiful *Tellina* (*T. manumissa* MS.) hitherto compared with *T. madagascariensis*, a parti-coloured *Nassa* (*N. Polychroma*), and many other interesting novelties. These have been described in the *Ann. & Mag. Nat. Hist.*, March, 1898, pp. 194-206.

The PRESIDENT exhibited specimens of silicified wood found in Egypt. Similar deposits occur in Auvergne, Arizona, Ireland, and elsewhere. The Egyptian deposits are situate in Wadies, south of Cairo. The source of the siliceous fluid is not known, but it may perhaps have been derived from volcanic districts lying to the East. Entire tree-trunks do not occur, only fragments, broken up possibly by rapid changes of temperature.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, January 17th, 1898.

MARK STIRRUP, F.G.S., President of the Section, in the Chair.

Mr. Mark L. Sykes, F.R.M.S., Ardwick, was elected an Associate of the Section.

Mr. CHARLES BAILEY exhibited a large number of specimens of a floating fern *Salvinia natans* Willd., found plentifully in ponds round Berlin and generally throughout Northern Europe, but not as yet noticed in this country. He described in detail the floating leaves, the pendant, submerged, root-like leaves, and the fructification.

Mr. MARK SYKES exhibited several specimens of Termites, so-called white ants, recently received from Sierra Leone, also their nests, the arrangement and construction of which he described.

Mr. J. F. ALLEN exhibited a number of manganese alloys, some of which, after being submitted to a severe strain, had recovered their elasticity after a lapse of about three weeks.

Mr. PETER CAMERON contributed a paper on "**Hymenoptera Orientalia, or Contributions to a knowledge of the Hymenoptera of the Oriental Zoological Region,**" Part VII.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, February 14th, 1898.

JOHN BOYD, Vice-President of the Section, in the Chair.

Mr. ROGERS exhibited a new species of land shell, which had recently been discovered in Lord Howe Island by Mrs. Waterhouse, of Sydney, and had now been named *Endodonta Waterhousia* by Mr. Hedley, of the Australian Museum. Mr. Rogers also showed several new species of land shells from Trinidad, which had been recently discovered by Mr. W. Lunt, Assistant-Superintendent at the Royal Botanic Gardens, Trinidad. Mr. Lunt has been fortunate in adding considerably to the list of molluscs hitherto found in that island.

Mr. ROGERS afterwards made some remarks on the habitats and geographical distribution of a small British mollusc *Achatina acicula*, an earth-burrowing mollusc, often found in and about ancient burial places, specimens having been found in the so-called tear-bottles found in the graves of ancient Greece. It has now been found in South Africa.

The rest of the evening was devoted to the microscopes.

[*Microscopical and Natural History Section.*]

Ordinary Meeting, March 14th, 1898.

MARK STIRRUP, F.G.S., President of the Section, in the Chair.

Mr. John Mullen, Oldham, and Mr. W. Stanley, Weaste, were elected Associates of the Section.

Mr. J. F. Allen and Mr. W. R. Scowcroft were elected auditors.

The PRESIDENT read a paper on "**The Composition and Structure of Spore-Coals and Bogheads,**" illustrated by hand specimens and thin sections under the microscope, by which the fundamental characters were shown which distinguish spore-coals and the class of oil shales known as bogheads. The differences which present themselves were shown to be mainly due to the original plant organisms of whose fossilised remains the spore-coals and bogheads were composed. The "better-bed" coal of Bradford and the Tasmanite mineral of Tasmania were selected as examples of coals owing their special properties to spores, or to the reproductive organs of certain cryptogamic plants of doubtful origin, but whose probable relationship is considered by Sir William Dawson to be with the Rhizocarpeæ. On the other hand, the combustible part of bogheads, such as the Torbane Hill mineral of Scotland, the boghead of Autun in France, and the kerosene shales of Australia, owed their remarkable properties to the vast accumulations of microscpic algæ of a very low order, and so far as is yet known, without any actual living representatives. Science is indebted for the latter facts to the long-continued investigations into the nature of bogheads carried on by Professors Renault and Bertrand in France.

Mr. MARK SYKES made a short communication on mimetic forms among Lepidopterous insects, showing some fine characteristic specimens of the genus *Kallima*, including *K. inactus*, *K. paralekta*, *K. albofasciata*, *K. philarchus*, and *K. Wardii*, from N. and S. India, Siam, Java, Ceylon, and the Andaman Islands.

Mr. ALLEN exhibited some specimens of an alloy of manganese and silver.

Mr. BROADBENT described Sarcina, an organism observed by him in manure water.

[*Microscopical and Natural History Section.*]

Annual Meeting, April 4th, 1898.

MARK STIRRUP, F.G.S., President of the Section, in the Chair.

Dr. Booth, Swan Street, Manchester, was elected an Associate of the Section.

The Annual Report of the Council and the Treasurer's Statement of Accounts were submitted and approved.

The following officers and Council were elected for the Session 1898-99: President, JOHN BOYD; Vice-Presidents, CHARLES BAILEY, F.L.S., J. COSMO MELVILL, M.A., F.L.S., MARK STIRRUP, F.G.S.; Treasurer, G. H. BROADBENT, M.R.C.S.; Secretary, T. SINGTON; Council, J. F. ALLEN, W. E. HOYLE, M.A., H. HYDE, F. NICHOLSON, F.Z.S., T. ROGERS, C. H. SCHILL, W. R. SCOWCROFT.

Mr. BROADBENT described some observations made by him on Vorticellæ, their life-work and mode of attachment.

Mr. BUTTERWORTH described and exhibited an apparatus for observing the development of low forms of aquatic life, consisting of a circular metal plate with a rim, containing several layers of flannel, kept well moistened, covered with a glass shade, under which is a zinc frame with trays for the brass or glass animalculæ troughs or slips. With this apparatus the objects to be studied can be watched day by day for weeks, the daily changes being easily noted.

Mr. STIRRUP exhibited zircons, garnets, and sapphires occurring in the volcanic rocks of Le Puy, Haute Loire, France. Those shown were found on Mont Mezen. They also occur in volcanic rocks, near the Rhine, at Andernach.

Mr. T. ROGERS exhibited a number of fresh-water shells collected from mud flats at Loando, Africa, all the specimens being sinistral. They included three species of *Melodomus* from Zanzibar, Zululand, and the Quanze River, Angola, S. W. Africa respectively. The species of *Melodomus* are nearly allied to those of *Paludina* and *Ampullaria*.

Special Meeting, March 29th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The meeting was specially convened for the presentation of the Wilde and Dalton Medals and of the premium, and for the delivery of the Wilde Lecture for 1898. There was a large attendance of members and friends.

The PRESIDENT, in his opening remarks, referred to the fact that last year, when the Wilde Medal was presented for the first time, Dr. Schunck stated at length the particulars of the generous benefactions of Mr. Wilde, and said that it was, therefore, not necessary to again speak of these except to express their continued sense of indebtedness to Mr. Wilde. The Wilde Medal for this year had been awarded, by the unanimous vote of the Council, to Sir JOSEPH DALTON HOOKER, G.C.S.I., C.B., F.R.S.

In presenting the Wilde Medal for 1898 to Sir Joseph Hooker, the President spoke as follows:—

"The name of Hooker has been associated with botanical progress during nearly the whole of the present century. Sir William Jackson Hooker, the father of Sir Joseph, had been appointed, in 1820, Regius Professor of Botany at Glasgow University, and, in 1844, was made Director of Kew Gardens, which post he held until his death in August, 1865, being succeeded by his son, who continued to hold the office for more than twenty years. But Sir Joseph is also known to fame as a traveller. His first journey, early in the forties, was to the Antarctic regions, including visits to New Zealand, the Auckland and Campbell Islands, the Strait of Magellan, and the Falkland Islands. The southernmost shores of Australia, particularly Tasmania, were also explored, the results being embodied in the *Floras of Tasmania and New Zealand*, and the *Botany of the Antarctic Voyage*. A few years later, in 1848, in company with Mr. Thomson, he essayed a comprehensive botanical journey to India, the first fruits of which were his delightful journals of the Himalayan region, and the beautiful work on the Rhododendrons

of the Sikkim Himalaya, likewise the first volume (all published) of a *Flora of India*. This was never finished in its present form, but his *magnum opus*, completed late last year in seven volumes, on the Flora of India, will remain for all time a memorial of its author. He might exclaim with Horace: 'Exegi monumentum ære perennius.' The twentieth century is hardly likely to improve upon the nineteenth in respect of Systematic Botany, and I think Sir Joseph is happy in having lived during a period in which such wonderful investigations and discoveries were possible. I would also like to mention the *Index Kewensis*, completed during the last decade of this century, a catalogue, arranged alphabetically, of all known phanerogamic plants, the idea of which, inaugurated by Charles Darwin, had, at his expense, been so well carried out by Mr. Daydon Jackson, under the auspices of Sir Joseph Hooker."

Sir JOSEPH HOOKER, in replying, said the great honour which the Society had conferred upon him by the award of the Wilde Medal was rendered doubly grateful by the fact that Manchester held a place amongst his very earliest botanical reminiscences. He was born a muscologist, and very early—in the first decade of the eighty years that had passed over him—he was a collector of mosses. He was stimulated in the pursuit by a book in his father's library bearing the title of "Musci Britannici," by Edward Hobson, of Manchester. Later on, when still in his teens, he aided a young Glasgow botanist in collecting specimens for a work he had in preparation on the lines of Hobson's. Manchester, indeed, was famous as a school of muscologists in the first half of the century, and he need not recall to their memory the names of John Nowell and Richard Buxton as forming, with Hobson, a celebrated trio, distinguished for their critical knowledge of British mosses. A well-remembered Manchester friend of his early youth was Thomas Glover, of Smedley Hill, an excellent botanist and entomologist. Mr. Glover invited him to Smedley Hill to see his beautiful collection of insects and rare garden plants, and, though this was 65 years ago, he noticed that the latter suffered a good deal from the city smoke. His

next visit to Manchester, after an interval of a dozen years or more, was to examine in the Museum some coal fossils for the Geological Survey of Great Britain, to which institution he was for a short time attached. Still later he had the pleasure of the friendship of Mr. Binney, who asked his assistance in investigating the flora of the coal measures. But of all his Manchester fellow-botanists there was none to whose friendship and correspondence he looked back with greater pleasure than to that of the famous palæo-botanist and accomplished naturalist Professor Williamson. It was indeed a privilege to be consulted by Professor Williamson, and to be kept informed of the progress of the wonderful collection he was making and illustrating with a disinterested zeal that overcame all obstacles. The magnificent series of papers on the organisation of the fossil plants of the coal measures which Professor Williamson presented to the Royal Society was unrivalled for the wealth of material they contained on that subject. As further examples of the influence of the Manchester school of botany, if he might so call it, he mentioned the names of the Rev. the Hon. W. Herbert, at one time Dean of Manchester, and the late Mr. Clowes, of Broughton. In concluding, Sir Joseph said that in accepting this gratifying assurance of the Society's sympathy for his labours he was far from regarding it as solely personal. No man could say that his merits, be they what they might, were all his own. For his own part, he could claim to have had a persistent love of knowledge for its own sake from his earliest years, but that would have availed him little had he not felt from the first the guiding hand of a parent who had himself attained eminence, and who, by example, precept and encouragement, kept him to his purpose, launched him in the fields of exploration and research, and liberally supported him as occasion required. He accepted the medal as a tribute to his father's memory as much as to his own exertions.

The President then presented to Dr. EDWARD SCHUNCK, Ph.D., F.R.S., the Dalton Medal—this being the first occasion on which this medal has been presented—and said that Dr.

Schunck might be called the "father" of the Society. He had been a member for 56 years, and had held the office of President four times. He had contributed most important papers on various dyes and colouring matters, and it was for these and the life-long services he had given for the advancement of science that the Council had awarded him the medal.

In his reply, Dr. SCHUNCK said that his labours had been confined to a very small department of chemistry, but a department which was very important. He would like very much, if he could, to add to these labours, but he was afraid that at his age it was hardly possible to do important work, and no doubt many would say that it was better that he should not attempt it. He had two or three irons in the fire, but whether he would ever take them out he did not know.

In handing the Wilde Premium for 1898 to Mr. JOHN BUTTERWORTH, F.R.M.S., the President stated that it had been awarded by the Council in recognition of the excellent work done by Mr. Butterworth, more especially in regard to the flora of the coal measures.

Mr. BUTTERWORTH expressed his thanks to the Society for the honour it had done him, and said that he had worked for nearly thirty years with the late Professor Williamson, and had contributed materials for a considerable portion of the memoirs. He regretted that in his early days he had not had the advantages of systematic instruction; with him it had been a case of the night school and the solitary candle. He had pursued the study of geology purely for the love of it, and had found great enjoyment among the flora of the coal measures.

This brought the first part of the proceedings to a close. The members then adjourned to the Library, where the Wilde Lecture, "**On the Physical Basis of Psychical Events,**" was delivered by Professor MICHAEL FOSTER, M.A., SEC. R.S. At the conclusion of the Lecture, a hearty vote of thanks was accorded to Professor Foster, on the motion of the PRESIDENT, seconded by Professor LAMB, F.R.S.

The Lecture is printed in full in the *Memoirs*.

Ordinary Meeting, April 5th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. BROTHERS communicated a note on stereoscopic and pseudoscopic vision, with the object of eliciting views as to whether, when the stereoscopic effect of stereoscopic pictures is seen without the use of an instrument, the effect can be said to be caused by "squinting."

A discussion followed, in which opinion was divided as to whether squinting was the correct definition of the cause. It was held that for true stereoscopic vision the axes of the eyes are constrained to be parallel, and that the term squinting applied more properly to the crossing of the axes which produces the inverted stereoscopic appearance. In both cases, there is an unnatural strain if that constitutes squinting.

Mr. F. J. FARADAY communicated a paper by Professor SUESS, of Vienna, on "**The New Gold Discoveries.**"

The paper is printed in full in the *Memoirs*.

Mr. W. E. HOYLE described a bone supposed to be the pelvic bone of a whale.

Mr. H. BOLTON read a paper entitled: "**The Palæontology of the Slates of the Isle of Man,**" and exhibited several specimens to illustrate it. After a critical summary of previous literature, the author described the occurence of characters of certain worm-burrows and castings, graptolites, and the impression of a trilobite. It was shown that, notwithstanding the work of geologists for nearly a hundred years, not more than half-a-dozen species of fossils from slate are yet known, and that these are not sufficient of themselves to determine the stratigraphical position of the Slates, which is, therefore, still uncertain.

Mr. Bolton was of opinion that the specimens he exhibited

and described indicated an horizon between the Lingula Flags and the Arenig Series.

The paper will be printed in full in the next volume of the *Memoirs.*

Annual General Meeting, April 19th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The Annual Report of the Council and the statement of accounts were presented, and it was resolved :—"That the Annual Report, together with the statement of accounts, be adopted, and be printed in the Society's *Proceedings.*"

On the motion of Mr. CHARLES BAILEY, seconded by Mr. NICHOLSON, it was resolved :—"That the system of electing Associates of the Sections be continued during the ensuing session."

The following members were elected officers of the Society and members of the Council for the ensuing year :—

President: JAMES COSMO MELVILL, M.A., F.L.S.

Vice-Presidents: OSBORNE REYNOLDS, M.A., LL.D., F.R.S.; ARTHUR SCHUSTER, Ph.D., F.R.S.; CHARLES BAILEY, F.L.S.; W. H. JOHNSON, B.Sc.

Secretaries: R. F. GWYTHER, M.A.; FRANCIS JONES, F.C.S.

Treasurer: J. J. ASHWORTH.

Librarian: W. E. HOYLE, M.A., M.Sc.

Other Members of the Council: HAROLD B. DIXON, M.A., F.R.S.; HORACE LAMB, M.A., F.R.S.; FRANCIS NICHOLSON, F.Z.S.; J. E. KING, M.A.; R. L. TAYLOR, F.C.S.; F. J. FARADAY, F.L.S.

Ordinary Meeting, April 19th, 1898.

JAMES COSMO MELVILL, M.A., F.L.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. CHARLES BAILEY exhibited some living plants of Jacquin's oxlip (*Primula elatior*), which he had gathered ten days ago in a wood on Mrs. Rayment's estate at Tindon End, near Thaxted, Essex. He pointed out its peculiar distribution in England—where it is confined to an area within the triangle formed between St. Neots in Huntingdon, Stowmarket in Suffolk, and Bishop Stortford in Hertfordshire—and explained the botanical characters which separate it from the primrose and cowslip. Mr. Miller-Christy in his very interesting paper, read before the Linnean Society last November, refers to the strong scent of the oxlip, but Mr. Bailey in the large number of plants he examined last week in Essex, was rather struck with the absence of odour in the oxlip, especially compared with the cowslip or primrose. With it he exhibited a flower-scape, from a root which he brought some years ago from Gloddaeth, near Llandudno, which was a natural hybrid between the cowslip and the primrose, and which flowered every spring in his garden. Such hybrids generally pass for the true oxlip; and they are not infrequent in districts where both parents occur; in the neighbourhood of Manchester he had found this spurious oxlip at Ashley, at Mobberley, and in several places in Derbyshire.

Annual Report of the Council, April, 1898.

The Society began the session with an ordinary membership of 161. During the present session 7 new members have joined the Society; 9 resignations have been received, and the deaths have been 7, viz.: Rev. G. H. G. Anson, M.A.; Mr. Thomas Ashton, LL.D.; Mr. William Grimshaw; Mr. Peter Hart; Mr. James Heelis; Mr. James Heywood, F.R.S., F.G.S.; and Mr. John Ramsbottom, M.Inst.C.E. This leaves on the roll 152 ordinary members. The Society has also lost 4 honorary members by death, viz.: Francesco Brioschi; Professor Victor Meyer, Ph.D.; Professor Julius von Sachs, Ph.D., For. Mem. R.S.; and Professor E. J. Stone, M.A., F.R.S. Memorial notices of these gentlemen appear at the end of this report.

The Treasurer commenced the year with a balance in favour of the Society of £375. 4s. 3½d. (including £63. 4s. 2d., balance of the Wilde Endowment Fund), and reports that the total balance, including the Wilde and Joule Funds, and not including the amount still owing by the Natural History Fund, in hand and at the bankers, at the close of the year, is £236. 10s. 7d.

The state of the floor of the old Tea Room, above the Meeting Room, has for years been so unsatisfactory as almost to preclude the use of the room, and the renewal of the floor could not have been long delayed without danger. The constant growth of the library has also made the provision of additional bookcases a matter of almost immediate urgency. The floor has, therefore, been relaid in so substantial a manner that it will now carry the weight of bookcases, and the room will constitute a material addition to the space which can be used for library purposes.

The re-cataloguing of the library has been continued during

the session, 6,063 volumes having been catalogued, stamped, and pressmarked, 5,537 of these being serials, and 526 separate works. The latter belong to the following branches of science: Astronomy, Botany, and Medicine. There have been written 2,016 catalogue cards; 1,400 for serials, and 616 for separate works. The total number of volumes catalogued to date is 8,744, for which 3,290 cards have been written, and for these latter a cabinet has been purchased, which now stands in the Secretaries' room.

The shelf list, which was commenced last session, has been continued, and will prove useful to members as a subject-index to the separate works.

During the session, 234 volumes have been borrowed from the library, as compared with 124 volumes in the previous session, and it is hoped that, as the cataloguing progresses and affords increased facilities for quickly finding any work required, members will make still further use of the valuable collection of books possessed by the Society.

Especial attention has been paid to the completion of sets, where possible, with the result that 189 volumes or parts have been obtained which render 32 sets complete, whilst 210 volumes have been acquired which partly complete 37 sets. Of this total of 399 volumes, 155 were purchased (including 76 volumes of the *Annales de Chimie et de Physique* and 48 volumes of the *American Journal of Science*), the remainder being presented by the respective societies publishing them.

Slightly less binding has been done than last session, 363 volumes having been bound in 301, whilst 17 volumes have undergone repair. There are about 4,000 volumes in the library still unbound, which number is constantly being added to, so that in order to overtake the arrears of binding within ten years, and to provide for the annual increase in the library during that time, it will be necessary to bind about 800 volumes, at an approximate cost of about £100, each year.

During the three months January-March, 1898, a record has been kept of the accessions to the library, showing that, during that period, 261 serials and 11 separate works were received, a total of 272 volumes. The donations during the session (exclusive of the usual exchanges) amount to 68 volumes and 120 dissertations; and 9 books have been purchased (in addition to the periodicals on the regular subscription list).

The Society has arranged to exchange publications with the following: Conchological Society of Great Britain and Ireland; Université de Lyon; Göteborgs Stadsbibliotek; *Kansas University Quarterly*, Lawrence; Missouri Botanical Garden, St. Louis; and the Queensland Museum, Brisbane.

The undermentioned periodicals have been added to the list of those subscribed for by the Society:—*Natural Science* (London); *Proceedings of the Malacological Society* (London); *Science Progress* (London); *Zoologische Jahrbücher* (Jena); *Journal für Ornithologie* (Leipsic); *Mathematische Annalen* (Leipsic); *American Journal of Science* (New Haven); and *The Auk* (New York).

The printing of the list of serial publications referred to in the last report has been delayed owing to the decision of the Council to make a catalogue of the scientific serials available in Manchester, as far as lists can be officially obtained, with an indication of the libraries in which they are to be found. The negotiations have made considerable progress.

The Council appointed the Assistant Secretary and Librarian to represent the Society at the second International Library Conference, which met in London in July last, and was attended by a large number of delegates from Great Britain and abroad.

The Council has awarded:—

The Wilde Medal for 1898 to Sir Joseph Dalton Hooker, G.C.S.I., C.B., F.R.S., in recognition of the eminent services he has rendered to all branches of botanical science;

A Dalton Medal (struck in 1864) to Dr. Edward Schunck, F.R.S., for the remarkable series of researches on the natural

colouring matters with which he has enriched Chemistry, and in appreciation of the life-long services which he has rendered, in particular, to the advancement of science in Manchester; and

The Wilde Premium for 1898 to Mr. John Butterworth, F.R.M.S., for his memoir read before the Society on "Some further investigation of fossil seeds of the genus *Lagenostoma* (Williamson) from the lower coal measures, Oldham," in continuation of his researches in the structure of fossil plants of the coal measures.

Professor Michael Foster, Sec.R.S., was appointed to deliver the Wilde Lecture.

The Council arranged that the Medals should be presented and the Wilde Lecture delivered on Tuesday, March 29th, 1898

Professor FRANCESCO BRIOSCHI was the author of many highly original investigations in Pure Mathematics and Analytical Mechanics. He was associated with Hermite in the development of the Theory of Invariants founded by Boole, Cayley, and Sylvester, and made notable contributions to the Theory of Equations and to Solid Geometry. He held many important scientific posts; in addition to his official position as Director of the Milan Polytechnic, he was editor of the *Annali di Matematica*; and the great veneration in which he was held by his colleagues in Italy is shewn by the fact that he was made President of the Accademia dei Lincei in 1884, and thereafter regularly re-elected at the expiration of each quadrennial period. He was a Senator of the Kingdom of Italy, and at various times did work of a more or less official character in connection with the Budget, the organisation of the railway system, and the Department of Public Instruction. He died on December 13th, 1897, at the age (almost) of 73 years. He had been an honorary member of our Society since 1892.

A highly appreciative account of his scientific labours appeared in the *Comptes Rendus* for December 27, 1897, from the pen of his friend and collaborateur, Hermite. H. L.

By the death of VICTOR MEYER, the Society loses one of its most distinguished honorary members, and science one of its greatest teachers and discoverers. He died young—he was not quite forty-nine—and it might have been hoped that there were many years of work still before him, but his health broke down, and, worn out with pain and insomnia, he committed suicide on August 8, 1897.

Victor Meyer began his chemical studies under Bunsen, at Heidelberg, and continued them under Baeyer, at Berlin. He held appointments successively at Stuttgart, Zürich, Göttingen, and finally, at Heidelberg, where he succeeded to the chair of Chemistry on the retirement of Bunsen.

It is impossible here to give details of his investigations, which began about 1870, and were continued till his death; it must suffice to mention some of the most important. He discovered nitro-ethane and its homologues, and by acting on these bodies with nitrous acid, he obtained nitrolic acid and pseudo-nitrols. Ten years later he found that iso-nitroso compounds are formed by the action of hydroxylamine on aldehydes and ketones, and that this reaction is of general application.

In 1882, Meyer discovered in ordinary benzene a new constituent, to which he gave the name thiophene; and, in 1888, he was able to publish, under the title of "Die Thiophen-gruppe," a very complete account, not only of this interesting body, but of many of its derivatives. Mention must also be made of his discovery of the oximes and of the group of bodies obtained from the hypothetical iodonium hydroxide.

Lastly, but certainly not least in importance, is Victor Meyer's work on vapour density, and the simple methods he devised for making that important determination. The earlier methods were *direct*—a certain volume of the vapour was obtained and its weight ascertained, or a definite weight of a substance was vaporised, and the volume occupied by the vapour ascertained—but they were liable to error, and difficult to execute. It was reserved for Victor Meyer to show how much easier it was to make the method *indirect*—to volatilize a definite weight of the

substance in a suitable apparatus and measure the volume of air it displaced. The advantages of the new method were speedily recognized, and its use is now universal. It falls to the lot of comparatively few chemists to invent an apparatus or discover a process which is adopted in every laboratory; this is certainly the case with Liebig and with Bunsen, and to their honoured names must be added that of Victor Meyer. F. J.

By the death of JULIUS SACHS, on May 29th, 1897, one of the most ardent workers in Botanical Science has been lost. Not only have his labours largely enriched our knowledge of Plant Physiology, which he had made his special study, but his infectious enthusiasm for this branch of Botany has caused enormous advances to be made by those Botanists who were privileged to work under his stimulating guidance. Among these are numbered most of the Vegetable Physiologists both of England and the Continent, including such men as Francis Darwin, Vines, Marshall Ward, Brefeld, Pfeffer and Reinke. Born in 1832, in Breslau, Julius Sachs received from his father, an engraver, considerable encouragement for the development of his artistic faculties, and his early training in drawing and painting stood him in good stead in afterlife. His enthusiasm for Natural History, however, was kindled by his intercourse with the sons of the physiologist Purkynje, with whom he went out collecting plants for the herbarium which he commenced while at school. Later on, when Purkynje was appointed to the University of Prague, he engaged Sachs as his draughtsman. His connection with Purkynje no doubt determined the direction of his subsequent work, and, after having taken his degree at Prague, he established himself there as lecturer in Vegetable Physiology—a branch of Botany which it was usual at that time to dismiss with a very few words. Largely owing to Sachs's labours, however, Vegetable Physiology is now so extensive a subject that it forms a very considerable portion of the study of Botany.

From Prague Sachs proceeded to Tharandt in 1859, to work out the agricultural bearings of Vegetable Physiology. He

then lectured successively at Bonn and Freiburg, and finally was called to the University of Würzburg, where he established himself definitely, in spite of many tempting offers from the Universities of Munich, Berlin, and Vienna.

It is with Würzburg that Sachs's name will always be associated, and it is here that most of that work was done which made Sachs the founder of Modern Vegetable Physiology.

His first publication, summing up the older experiments in Plant Physiology, with the incorporation of the results of his own researches, was the *Handbuch der Experimental-Physiologie der Pflanzen*, published, in 1865, as the 4th volume of Hofmeister's *Handbuch der physiologischen Botanik.*

Then followed his well-known *Lehrbuch der Botanik*, which rapidly passed through four editions, and was translated into English and several other languages.

In 1875 appeared the *Geschichte der Botanik*, an admirable example of what a history of science should be, and which shows his critical faculty at its best. This, as well as his Lectures on the Physiology of Plants, was translated into English. His numerous papers are characterised by the trenchant criticism of his opponents, and by the clear and concise language which he employed in the skilful unfolding of any new results obtained by his carefully thought-out experiments.

Sachs was elected an honorary member of this Society on April 30th, 1872. A complete list of his papers will be found at the end of the excellent biographical notice, by Professor Goebel, in volume 84 of *Flora.* F. E. W.

EDWARD JAMES STONE was born in London on February 28th, 1831. His early education was frequently interrupted owing to ill health, and his systematic education really began when he entered King's College, London, at the age of twenty-one. In his twenty-fourth year he entered Queen's College, Cambridge, and was fifth Wrangler in 1859.

In 1860, Mr. Stone was appointed First Assistant at the Greenwich Observatory, where he remained ten years. In 1870,

he obtained the appointment as Astronomer Royal at the Cape Observatory, which he held till, in 1878, he was appointed Radcliffe Observer at Oxford.

In the positions which Mr. Stone held he devoted himself assiduously to problems of the astronomy of position, and especially to meridian observations. As evidence of his industry, the Royal Society *Catalogue of Scientific Papers* contains the titles of 92 of his papers antecedent to 1883.

It is not here possible to discuss his work at length; fuller notices will be found in the *Monthly Notices of the Royal Astronomical Society* (vol. 58, p. 143), and in the *Proceedings of the Royal Society* (vol. 62, p. x.).

Mr. Stone was elected an honorary member of the Society on April 17th, 1894.

Mr. Stone's death took place, from cardiac failure during an attack of pneumonia, on May 9th, 1897. Only a week previously, during a visit to North Wales to fish (a pursuit of which he had always been very fond), his boat had been upset, and, to avoid a chill, he rowed quickly a distance of two miles to his hotel. It was supposed that he unfortunately overstrained his heart, and that the accident was the cause of his fatal illness.

On the day before his death he was at the Observatory, making arrangements for trial observations, preparatory to observing the total solar eclipse in India in 1898.

The Ven. GEORGE HENRY GREVILLE ANSON, M.A., third son of General Sir William Anson, was born on July 19, 1820. he received his education at Eton, Charterhouse, and at Exeter College, Oxford, where he graduated in 1843. He was ordained the same year, and appointed to a curacy at Leeds Parish Church under his future father-in-law, Dr. Hook. Here he remained for three years, when he was nominated by his eldest brother, the late Sir J. W. H. Anson, to the incumbency of St. James's, Birch-in-Rusholme, which he held until his death. In 1848 he was appointed examining chaplain to Dr. Prince Lee, then Bishop of Manchester, and, on Bishop Fraser's nomination

to the See in 1870, was appointed Archdeacon in succession to Dr. Durnford. Bishop Fraser's regard for him was further shown by his offering the Archdeacon, in 1882, a residentiary canonry in the Cathedral, which was accepted. He did not hold the office long, however, for the death of Canon Gibson, in 1884, left him no alternative but to give up Birch Rectory and take the rectory of St. Matthew's, Campfield, or to resign his canonry. His strong family associations with Birch inclined him to the latter course, and six years later (in 1890) he also resigned the archdeaconry, being of the opinion that the duties of the office required a younger man.

Archdeacon Anson was a governor of the Hulme Trust Estates, a feoffee of Chetham Hospital and Library, and was also interested in the St. Mary's Home, Rusholme (which he founded), in the Manchester Southern Hospital, and in St. Mary's Hospital. He married, in 1848, Augusta Agnes, eldest daughter of Dr. Hook, who survives him. He was elected a member of this Society on January 22, 1861, and was always interested in its proceedings, though of late years he was seldom seen at the meetings. His death took place at Winchester on February 8, 1898, the remains being brought to Manchester and interred in Birch churchyard.

THOMAS ASHTON, LL.D., who died at his residence, Ford Bank, Didsbury, on January 21st last, was elected a member of the Manchester Literary and Philosophical Society, August 11th, 1837. Mr. Ashton was well-read in many subjects, and in full sympathy with both literary and scientific men. An interest in philosophical as well as in historical studies had remained to him, perhaps from his Heidelberg days; and the pleasure which he took in the conversation of the late Professor Huxley, when his guest at Ford Bank, in 1870, is vividly remembered by those who saw them together. But his field of action lay elsewhere than in the world of letters and science, though he was brought into close contact and connection with it through his services to higher education. Of these the most conspicuous

consists in the leading part taken by him in extending, and placing on a basis of permanent efficiency, a Manchester institution which, before the close of his career, had taken the foremost place among English University Colleges of the Victorian type. When, in 1892, Mr. Ashton received the Freedom of the City of Manchester—the only public honour which he ever accepted—his services to educational progress were justly placed in the forefront of the record of the benefits conferred by him on his native county.

Born at Hyde, in 1818, as the descendant of an old and wealthy Lancashire family of manufacturers, Mr. Ashton from his early manhood onwards closely engaged in the business of the great industrial house of which he was ultimately to become the head. But from an early date he found ample opportunities both for the exercise of a political activity, of which it is sufficient to say here that he came to be recognised, during a period of many years, as one of the leaders of his party in the North of England, and for exertions on behalf of the welfare and progress of the population at large, as well as of those sections of it with which he was brought into personal relations as an employer of labour. He was one of the most active members of the Cotton Famine Relief Committee of 1862, and was identified with the success of the Arts Treasures Exhibition of 1857. He was afterwards the first deputy-chairman of the Art Gallery Committee of the Corporation, and was well known as a private collector of remarkable judgment. For several years he held the Chairmanship of the Governing Body of Hulme's Charity, to the reconstitution of which his own efforts had largely contributed, and the Treasurership of the Manchester College (now at Oxford). He was also an active member of the Governing Bodies of the Manchester Grammar School and other institutions, among which he took a special interest in the progress of the Technical School at Hyde. He was for many years a Justice of the Peace and Deputy Lieutenant for Lancashire, and in 1884, held the office of High Sheriff of the County.

With the Owens College Mr. Ashton first became closely associated in 1867, when at the instance of Professor (now Sir Henry) Roscoe, F.R.S. he consented to become Chairman of the Committee then appointed for the extension of the College. The work of his Committee was completed in seven years, during the course of which it achieved the re-building of the College on a new site and scale, the entire reorganisation of its constitutional and administrative system, involving protracted Parliamentary proceedings, an extraordinary development of its instruction in class rooms and laboratories, and something like a trebling of its financial resources. Mr. Ashton, besides being one of the most liberal of the benefactors of the reconstituted College, with which he helped to bring about the incorporation of the Manchester School of Medicine, was one of the most energetic and sagacious members of its governing body, and remained a working member of its Council during the rest of his life. He had an important share in the transactions which, in 1880, resulted in the foundation of the Victoria University, which, without his advice and encouragement, would have remained an academic dream. In 1895, the University had the satisfaction of conferring upon Mr. Ashton its honorary degree of Doctor of Laws. The College possesses no outward memorial of his long and unwearying labours on its behalf, with the exception of a copy of the First Folio Shakspere placed as a tribute to his services in the Christie Library by Mr. Edward Donner, a member of the Council. But his name is unlikely to be forgotten in the College of which he was the Second Founder, in the University into the conception of which he entered with invaluable readiness, or in the City where he was for many years looked up to as an example, than which this age has known no better, of a true Manchester man.

Mr. Ashton married, in 1851, Elizabeth, daughter of Mr. S. S. Gair, of Liverpool, who survives him. His eldest son, Mr. Thomas Gair Ashton, is M.P. for the Luton division of Bedfordshire. His second son, Mr. Mark Ashton, died in 1895. His eldest surviving daughter is the wife of the Right Hon. James Bryce, M.P.

A. W. W.

WILLIAM BROCKBANK was born in St. John Street, in this city, in 1830, which year saw the opening of the Manchester and Liverpool Railway, in the construction of which his father had been largely concerned, building the bridge over the Irwell and supplying the hurdles upon which the line was carried over Chat Moss. At his father's house young Brockbank met Dixon, Locke, and other engineers, which gave his mind a bent which led his father to have him apprenticed to his cousin, Mr. Thomas Carrick, then a well-known Manchester surveyor. In 1853, a partnership was entered into, under the style of Carrick and Brockbank; the firm was largely engaged in railway surveys, and the *staking out* of new lines; the firm also made the surveys of the Manchester Corporation Waterworks, as well as the greater part of the plans (now in the Town Hall) of the completed works, including the Thirlmere Parliamentary Surveys, in which the leading share was taken by Mr. T. Silk Wilson, who had become a partner in the firm; Mr. Brockbank, in the meanwhile, had retired from it and was devoting his attention to his large and increasing business as metal merchant in Manchester and Birmingham, which became very considerable; but, like many other very busy men, he found time to benefit the culture and comfort of those with whom he was brought in contact.

A descendant of a family who joined the Society of Friends on its foundation by George Fox, Mr. Brockbank took an active interest in their welfare. He had an important share in the initiation and founding of Dalton Hall, a hall of residence in connection with the Owens College, in Victoria Park, which was opened in 1882, and has since served as a model for several other halls of residence in connection with other provincial colleges. The scheme for such an institution was formulated by Mr. Brockbank, and was carried on experimentally in Lloyd Street, Greenheys, as the Friends' Hall, and its success led to the larger undertaking in Victoria Park, which has more than answered the expectations of its founders.

Mr. Brockbank had a very strong individuality, his imposing figure and presence, massive handsome head, and his courteous

but decisive method of speaking, will not readily be forgotten by those who came in contact with him. He appears to have early acquired a taste for scientific pursuits, especially in geology and horticulture, his first paper in the *Proceedings*, dating back to 1859, and that of 1861 deal with metallurgical subjects. From 1864 a succession of geological papers appeared, but these only represent a very small part of the varied information he collected, more especially the extensive series of water-colour sketches with which he illustrated his notes, which combined much artistic merit, with the careful draughtsmanship of a surveyor. His artistic instincts enabled him to form a very interesting collection of modern English art, many examples of which were exhibited at the Manchester Jubilee Exhibition. When the writer was associated with Mr. Brockbank in 1890, in working out the details of the Levenshulme railway cuttings, the results of which is published in the Society's *Memoirs*, he was struck with the fertility of resource he exhibited on various occasions, as for instance, when a strange granite boulder occurred in the railway cutting, he wrote to all the postmasters in Cumberland and Westmoreland in the neighbourhood of granite bosses, to kindly ask a local quarryman to send samples of the granites of the district, enclosing a suitable recompense; in several cases this plan was most successful in producing specimens. He was much interested in glacial geology, and rescued several important erratics from destruction; one was placed in the area around the Friends Meeting House at St. Helens, many others he had placed in his beautiful garden at Didsbury. In this garden also were preserved samples of all the different limestones met with in the Levenshulme railway cutting, and several specimens of the old wooden water pipes, that originally distributed water to Manchester.

To the botanist and the horticulturist the garden was of the greatest interest. In it he raised the beautiful double daffodil from seeds saved from double daffodils of previous growth. Here also he carried on a most interesting series of experiments with the crossing of various species of saxifrages with very remarkable results. His garden was an object of interest and pleasure,

not only to the initiated, but to more humble members of society, such as the boys employed on the Levenshulme railway contract, who were invaluable in collecting fossils from the Permians, to whom he gave a tea in his gardens to their infinite delight. Each boy collected his store of fossils day by day, and a cart was sent down every week for them; but the results were not so satisfactory as Mr. Brockbank and the writer had anticipated, through a collector with a carpet bag playing the part of the white bears in the Arctic cachées.

In following up a scientific matter to its source, Mr. Brockbank neither studied his time, or inconvenience, or money, when, with the business aptitude that characterized him, he saw there was an obvious chance of a successful result. He joined the Society in 1855. He was also a Fellow of the Geological Society, the Linnean Society, and the Glacialists' Association, of which latter he was a Vice-President. His death took place on September 18th, 1896. C. E. De R.

List of Papers read before the Society:—

[Note on Titanium from Iron Furnaces.] *Proceedings*, i. (1859), p. 99.

[Notes on the Bessemer Process of manufacturing Steel.] *Proceedings*, ii. (1861), pp. 146 and 153.

On the Discovery of the Bones of the Mammoth (*Elephas primigenius*) in a Fissure of the Carboniferous Limestone at Waterhouses, near Leek. *Proceedings*, iv. (1864), pp. 46-50.

Notes on a Section of Chat Moss, near Astley Station. *Proceedings*, v. (1866), pp. 91-95.

[On Hæmatite Iron Deposits.] *Proceedings*, vii. (1867), pp. 59-61.

The Hæmatite Iron Ore Deposits of Whitehaven; Notes on the Aldby Limestone, Cleator Moor. *Proceedings*, viii. (1868), pp. 51-56.

Notes on the Effects of Cold upon the Strength of Iron. *Proceedings*, x. (1871), pp 77-86.

[Notes on a Specimen of Mineral Wool, and on a Mode of Utilising Slag.] *Proceedings*, xi. (1872), pp. 78-79.

Notes on supposed Glacial Action in the Deposition of Hematite Iron Ores in the Furness District. *Proceedings*, xii. (1873), pp. 58-65.

[Note on Specimens of Iron manufactured by the old Bohemian process from Hematite Ores in the South of Europe.] *Proceedings*, xii. (1873), pp. 72-73.

Notes on the Victoria Cave, Settle. *Proceedings*, xii. (1873), pp. 95-103.

[On Granites from Ravenglass and Criffel.] *Proceedings*, xv. (1876), pp. 70-71.

On the Levenshulme Limestone: A Section from Slade Lane eastwards. [1883.] *Memoirs*, Ser. 3, viii. (1884), pp. 125-132; abstract in *Proceedings*, xxii. (1883), pp. 61-65.

[On the late Dean Herbert's Illustrations of Flowers.] *Proceedings*, xxv. (1885), pp. 43-46.

The Levenshulme Limestones. *Memoirs and Proceedings*, Ser. 4. iii. (1890), pp. 209-211.

Notes on Seedling Saxifrages grown at Brockhurst [Didsbury] from a single scape of *Saxifraga Macnabiana*. *Memoirs and Proceedings*, Ser. 4, ii. (1889), pp. 227-230.

[Notes on the Discovery of *Estheria minuta* var. *Brodieana* in the Lower Keuper Sandstone of Alderley Edge.] *Memoirs and Proceedings*, Ser. 4, iv. (1890), pp. 12-13 and 31-32.

[Note on a Cutting of *Boussingaultia baselloides*.] *Memoirs and Proceedings*, Ser. 4, iv. (1890), pp. 13-15.

On the Entomostraca and Annalida in the Levenshulme Mottled Limestone. *Memoirs and Proceedings*, Ser. 4, iv. (1890), pp. 47-52.—Supplementary Note, pp. 353-356.

On the Occurrence of the Permians, Spirorbis Limestones, and Upper Coal Measures at Frizington Hall, in the Whitehaven District. *Memoirs and Proceedings*, Ser. 4, iv. (1891), pp. 418-426.

On the Permians of the N.W. of England. Discovery of two Plant Beds in the St. Bees Sandstone, at Hilton, Westmorland. *Memoirs and Proceedings*, Ser. 4, v. (1891), pp. 66-76, plates 2-4.

On the Artificial Coloration of Flowers. *Memoirs and Proceedings*, Ser. 4, v. (1892), pp. 142-144.

Notes on Glacier Moraines in Cumberland and Westmorland. *Memoirs and Proceedings*, Ser. 4, ix. (1895), pp. 195-205, plates 4-6; abstract in *Proceedings*, x. (1870), pp. 19-25.

Papers written conjointly:—

On the Liassic and Oolitic Iron Ores of Yorkshire and the East Midland Counties. By EDWARD HULL and WILLIAM BROCKBANK. *Proceedings*, v. (1866), pp. 119-122.

Notes on the Geological Section exposed in the Railway Cutting from Levenshulme to Fallowfield. By WILLIAM BROCKBANK and C. E. DE RANCE. *Memoirs and Proceedings*, Ser. 4, iv. (1890-91), pp. 282-300, 339-352, plate 5.

WILLIAM GRIMSHAW was born at Church Kirk, four miles from Blackburn, in the parish of Whalley, Lancashire, on January 24, 1824. Church Kirk may be spoken of as the original home of the great calico-printing industry of the county, the father of

the first Sir Robert Peel having early erected a printworks there, which was speedily followed by the establishment of many of the most famous printing and Turkey-red dyeing works in the same locality. Indeed, it may be said that most of the printworks of the district were either direct offshoots of the works at Church Kirk, or were founded by men who were trained there. With this industry William Grimshaw was destined to be intimately associated, first as a workman and eventually as a drysalter and colour merchant on his own account in Manchester. Born in very humble circumstances, Grimshaw's early life was extremely hard, affording scanty opportunities for education in those days. While still a youth, however, he obtained employment at the Belfield Printworks, with which Dr. Edward Schunck, F.R.S., was then connected. Many years after, on his election, February 7, 1888, as a member of the Manchester Literary and Philosophical Society, Mr. Grimshaw expressed to the present writer his special pleasure on entering an institution with which Dr. Schunck had been so long and prominently associated, as it was to Dr. Schunck's efforts for the intellectual advancement of the workmen under his control at Belfield, by means of personal instruction, that Grimshaw attributed his own success in life. Whenever, in these recent years, there was a prospect of "the Doctor" presiding at the Society's meetings, or taking part in its proceedings, Mr. Grimshaw was certain to be found in his place as an attentive listener. Dr. Schunck has been good enough to give the writer of this notice an account of the Belfield period of Grimshaw's life. "I first knew William Grimshaw," he writes, "as an apprentice in the 'colour-shop' of the printworks with which I was connected. I found him an intelligent youth and one of remarkably open, ingenuous demeanour, in fact, decidedly superior to the average youth of his class. Generally speaking, the men working in the colour department of a printworks are more intelligent than others, from the fact, I suppose, of their meeting with phenomena which call for explanation from an inquiring mind. Well, I formed a small class—I don't think there were more than 14—for reading and study, all of them

being employed in the works in some capacity or other. The plan was for each attendant to have a copy of the text-book, and, after reading a paragraph or two, an experiment was introduced in illustration. I look back with pleasure to the hours spent with these honest fellows—they were so genial and unceremonious. I always thought it strange, however, that Grimshaw should attribute his success in after life to the time so spent; no doubt he was right, but it only proves again, what has often been said, that for successful growth an appropriate seed and a congenial soil conjoined are requisite. After my connection with the Belfield Printworks had ceased, I lost sight of Grimshaw, and did not see him again for many years. When we met again, he had attained a position very much superior to that of a working-man." Dr. Schunck adds:—"Grimshaw's case shows again what a large measure of intelligence, energy and moral fibre the best of our working-men possess. It is on such qualities widely distributed amongst her sons that the greatness of this country has been built up." When he had attained affluence, Mr. Grimshaw developed strong tastes for horticulture, and for pictures and *bric-à-brac*, the latter passion being largely encouraged by his long acquaintance with his attached friend, the late Mr. George Freemantle, the well-known musical critic. His collection of paintings by old and modern masters, of pottery and of specimens of Japanese art-workmanship was a very remarkable one. But he was much more than a collector: he had a true thirst for knowledge of the history and qualities of every article he purchased; and by diligent reading and study acquired an amount of information, and a judgment which impressed all who met him, and were truly extraordinary in one who had had such few opportunities for culture in early life. As a director of the Manchester Aquarium, Mr. Grimshaw was associated with the late Mr. Charles Moseley in a vigorous attempt to maintain that institution as a means of promoting the study of natural history in Manchester. He was also a member of the Council of the Royal Institution of Manchester, before the transfer of the building and collections to the Manchester Corporation. For many

years he was a member of the Executive Committee of the Certified Industrial Schools of Manchester, and was specially active in that capacity in the management of the Girls' Industrial School at Sale. He was also active as a member of the Music, Electric Lighting, and Gardens Committee in connection with the highly successful Royal Jubilee Exhibition (1887) in Manchester. He gave generous support and assistance in the arrangments for the "mammoth" meeting of the British Association in Manchester in the same year, and took a not less cordial and helpful part in promoting the movement for a memorial of Joule in Manchester, which resulted in the fine statue, by Alfred Gilbert, now in the Town Hall. The catholicity of his tastes is further evidenced by the fact that he was an equally well-known figure at Halle's Concerts and at the County Cricket Ground on match days. To his latest years, Mr. Grimshaw continued to have that "open, ingenuous demeanour" which Dr. Schunck observed in him as a youth, and a consistent and peculiarly attractive earnestness of spirit. When struck by the malady which terminated his life, he faced the inevitable with quiet courage and resignation, remarking that he had no reason to complain of the length of years allotted to him; and he continued almost to the end to visit his club daily, mainly, it appeared, for the purpose of distributing amongst his friends nosegays—which he carried inside his hat—from his own garden. He died at his residence, Stoneleigh, Sale, on March 14, 1898, and was buried at Brooklands. F. J. F.

Peter Hart was born at Orford, near Warrington, on June 6th, 1834. In the village school he received a plain education, and he there came under the notice of Mr. William Beamont, first Mayor of Warrington, a well-known solicitor and antiquarian, and, what was then rare, an enthusiastic educationalist.

Through this gentleman, Peter Hart, at the age of 10, obtained a situation in a solicitor's office at Tarporley, and he was subsequently employed in Mr. Beamont's own office at Warrington.

In the interval between these periods, young Hart had been for a short time at the Chemical Works of Messrs. Tennants, at Ardwick, Manchester, where his father, William Hart, assisted Dr. James Young, F.R.S., in the management. In 1849, he finally relinquished law and returned to the Chemical Works. After spending a short time in the office he was, to his intense satisfaction, drafted into the laboratory.

He took up chemistry enthusiastically and attended night classes at the old Mechanics' Institute, in Cooper Street, under Dr. Allen, and read diligently the chemical books in the library attached to Tennants' laboratory. "Graham," "Turner," and "Brande" were his oracles, and he often said in after life that if he did not acquire as much from them as he ought, he found out at least "how little he knew and how much there was to be known." The innate modesty of the man comes out in this typical expression.

In 1847 and the following years, came Young's great discovery of the shale oil process, experiments in which were conducted at Ardwick. In connection with this, in 1851, it was necessary to make some tons of solid caustic soda from liquid caustic. This is probably the earliest record of the manufacture of solid caustic soda in England. William Gossage was at this time experimenting (upon the concentration of vitriol) at the Ardwick works, and subsequently devoting his attention to the manufacture of caustic soda, took out his well-known patent in 1853.

In the year 1852, Young left Messrs. Tennants' to exploit his shale oil process, and Peter Hart became chemist to the works, at the age of eighteen, acting under his father who became manager.

The next year he published his first original paper "On a new method of estimating Tin in Native Peroxide of Tin Ore," in a periodical called *The Chemist*.

The tin compounds in those days were the mordants on which the dyers and printers mainly relied, the aniline colours not having been yet invented, the animal and vegetable kingdoms

supplied the basis of their colours. Numerous and mysterious were the names under which tin mordants were sold, "oxymuriate," "sulphomuriate," "purple spirits," "blue spirits," "scarlet spirits," "double muriate," and so on, there being in many cases a good deal more difference in the name than in the chemical composition of the substance.

About this time, in connection with this subject, he carried out important technical improvements in the manufacture of stannate of soda.

From this time forward Peter Hart was constantly engaged in original work of one kind or another, either in elaborating and improving the processes of manufacture carried on in the chemical works of Messrs. Tennants and elsewhere, or in improving or originating methods of analysis.

It is characteristic of him that, although his original papers are fairly numerous, yet the amount of work which he did in following out his ideas was very great indeed compared with the length of his communications. His results were presented complete and fully digested, a paper of a few pages representing generally months of work and perhaps the study of a year or two.

His genius was essentially practical and simple. Unnecessary elaboration was a *bête noir* to him. Unless he had satisfied himself beyond all possibility of doubt, and had actually used a new method of analysis continuously, and satisfactorily, he was very diffident about troubling the chemical world with it.

His method for the estimation of chromium in chrome ore is given by Fresenius in the fourth edition of his *Quantitative Analysis*. It consists in successive fusion with borax, carbonate of sodium, and nitrate of potassium, and was subsequently modified by Dittmar.

In 1860, when the noted *Dictionary of Applied Chemistry* was published, he, at the request of Sheridan Muspratt, wrote the article on "Sulphuric Acid Manufacture," a sufficient testimony to the fact that he was recognized as one of the leading technologists in his own subjects. In connection with the manufacture of sulphuric acid, in 1865 he devised an apparatus

for the rapid determination of sulphur dioxide in chamber gases. In 1858 a description of similar apparatus was given by F. Reisch, but it was more complicated and less suitable for removal from place to place. Hart devised an apparatus similar to that of Hart at a later date.

Peter Hart's connection with this Society began in 1862, when he was elected a member. He communicated several papers to the Society, the first being in 1867 "On the occurrence of Sulpho-cyanides in Gas Mains," in which was pointed out the great distance from the source at which this substance is often found in the mains and pipes, often at the distance of a mile. A year later he patented a method for recovering the nitrous gases from vitriol chambers, but the invention of the Glover Tower superseded his idea.

The principle of the anemometer for strong or weak drafts, described by Hart at the meeting of this Society on April 5th, 1870, has received recognition from Dr. Hobson, in *The Chief Alkali Inspector's Report* for that year, and from other authorities, although Swan in the *Transactions of the Newcastle Chemical Society* subsequently, in 1871, published an account of an anemometer of his own construction, which involves the same principle as that of Hart.

Original papers were communicated to this Society at intervals until he joined the Society of Chemical Industry, since then most of his papers have been read before the latter Society, which is more directly concerned with his province of technology.

In 1866, a serious accident happened at Messrs. Tennants' works to Mr. Hart, senior, which resulted in his death, and the management and full control of the works then devolved on his son Peter. Since the death of the subject of this memoir one of his sons again occupies a similar post, so that three generations of the same name have now been associated with these works.

In 1885, the situation of the Ardwick works of Messrs. Tennants had, by the growth of the city, become too confined, and their removal to the present site in Clayton threw upon Peter

Hart the duty of the entire reconstruction of a large modern chemical works. It is needless to say that under his capable superintendence a fine, well equipped establishment was speedily evolved.

In 1887, in connection with the concentration of sulphuric acid he made some very interesting and valuable researches into the protective action of a coating of gold on the platinum vessels used in this process. Heraeus carried this out practically in 1891. (*Jour. Soc. Chem. Ind.*, 1891, pp. 460, 773). He was one of the earliest members of the Society of Chemical Industry when it was established in Manchester, and after being a member of the Committee for many years, was elected Vice-Chairman of the Manchester Section in 1897.

Being educated in the old school of chemistry, Peter Hart grew up under the old system of notation and nomenclature, and remained wedded to them. He always "thought" in the grain-decem-Fahrenheit system and the old equivalents, though of course his recent papers were translated before publication into the modern system.

After about 50 years of work, his health began to fail in the early part of 1897, and, suffering a relapse in May, he died on the 30th of that month at his residence Gransmoor, Fairfield.

Apart from the loss to technical and practical chemistry, the removal of Peter Hart from the midst of those who knew him, came as the loss of a friend and comrade, and left a blank which will not soon be filled. The bright geniality of his presence, his never failing quaint humour, the direct simplicity and kindliness of his nature, secured affection for him where many are fated to be content with respect.

Appearances he scorned, the inner nature of a man was what appealed to his sympathy, and opinion and advice were tendered as freely as they were received by him. "I have scarcely known anyone who could not teach me something" he once remarked to the writer of this memoir, and this was typical of his attitude to the youngest student of science as to her most famous veteran.

The writer acknowledges gratefully the value of the assistance of Mr. Peter Hart's sons in revising this brief memoir.

A list of published papers is appended.

1853. A new method of estimating Tin in native peroxide of Tin Ore. *The Chemist*, Vol. 4, 1853, p. 337.

1854. On the estimation of Tin. *Chem. Gaz.*, Vol. 12, 1854, p. 176.

,, On an Anhydrous Persulphate of Iron. *Chem. Gaz.*, Vol. 12, p. 350.

1855. Description of a new Gas-Furnace. *Chem. Gaz.*, Vol. 13, p. 175.

,, Estimation of Chromium Sesquioxide in Chrome Ore. *Chem. Gaz.*, Vol. 13, p. 458. This method is given in Fresenius' *Quantitative Analysis*, 4th Ed., p. 387.

1859. Researches on a method of Nitrous Vitriol estimation, by the reaction with Urea. *Chem. Gaz.*, Vol. 17, p. 172. Quoted in Muspratt's *Dictionary of Chemistry.*

,, A modification of Fresenius' and Wills' apparatus adapted to the estimation of Limestone. *Chem. Gaz.*, Vol. 17, p. 174.

1860. Article on Sulphuric Acid manufacture in Muspratt's *Dictionary of Applied Chemistry.*

,, Article on the Explosive Properties of Mercuric Oxalate. *Chem. News*, Vol. 2, p. 46.

1865. An apparatus for the rapid determination of Sulphur Dioxide in Chamber Gases.

1867. Method for the estimation of Nitrous Acid in Nitrous Vitriol.

,, Note on the occurence of Sulphocyanide of Ammonium in Gas Mains. *Proc. Manch. Lit. and Phil. Soc.*, Vol. 7. pp. 9—10.

1868. Patent for the utilizing of the Nitrous Vapours from Sulphuric Acid Chambers. (Superseded by the Glover Tower which came into general use.)

1869. The rapid determination of Free Oxygen. *Chem. News*, Vol. 19, p. 253; *Proc. Manch. Lit. and Phil. Soc.*, Vol. 8, pp. 188—190.

1870. Description of a new Anemometer. *Proc. Manch. Lit. and Phil. Soc.*, Vol. 9, pp. 152—4; *Chem. News*, Vol. 21, p. 200. Lunge's *Sulphuric Acid and Alkali.* 1st Ed., Vol. 1, p. 331.

1881. A Sulphuretted Hydrogen Apparatus. *Proc. Manch. Lit. and Phil. Soc.*, Vol. 20, pp. 96—98.

1882. Estimation of Free and Combined Acid in the Residual Liquor of Chlorine Stills. *Jour. Soc. Chem. Ind.*, Vol. 1, p. 308.

,, Estimation of Chlorine existing as Hypochlorite and Chlorate in Bleaching Liquors. (*Ibid.*)

1884. On the Concentration of Sulphuric Acid. *Jour. Soc. Chem. Ind.*, Vol. 3, p. 355.

1885. Patent—method of Sulphurous Acid production for Bisulphite manufacture.

1887. Estimation of Sodium Hydrate and Carbonate in Commercial Soda Ash. *Jour. Soc. Chem. Ind.*, Vol. 6, p. 347.

1887. Method of cooling water for technical purposes. *Ibid*, p. 711.
1892. Patent—manufacture of Ferric Sulphate for sewage purposes.
1895. Treatment of Zinc Ores and Complex Ores containing Zinc. *Jour. Soc. Chem. Ind.*, Vol. 14, p. 544.
1896. A feed-water heater for technical purposes. *Jour. Soc. Chem. Ind.*, Vol. 15, p. 252.

H. G.

JAMES HEELIS.—In a large commercial centre like Manchester whose inhabitants are, broadly speaking, all workers, there must be many who have not the necessary leisure to develope to the full the talents with which they have been endowed by nature. Such persons look forward to the time when they can sever their connection with business and devote the autumn of their lives to the pursuit of the literary and scientific subjects which they can only follow in a dillettante fashion in their busier years.

Such a man was the late James Heelis, whose premature death in March last at the early age of 55 is to be deplored, not only from its happening far from his friends and from his home, but also from its coming at the very commencement of the period of leisure which he had earned by a business career of nearly 40 years.

Born in 1843, the sixth and youngest son of Stephen Heelis, formerly a well-known Solicitor of this city, James Heelis received the rudiments of his education at the Grammar School at Sandbach, in Cheshire, from which he was taken in 1861, at the age of 18, to be articled to his father. He was admitted a Solicitor in 1866, and in 1868, on the death of his brother, Thomas Heelis, he was taken into his father's firm. From this time until his retirement from business at the beginning of 1897, his life was almost wholly absorbed with his professional work, in the conduct of which his great abilities were widely recognised.

Outside the sphere of his business, James Heelis was emphatically one of those whose education is never completed; who never cease to cultivate and develope the tastes and talents which they possess, and who add to a discriminating choice of subjects a thoughtful and attentive appreciation of what they read.

Mr. Heelis was elected a member of the Society in 1873, and though unable to devote himself to original research, he was keenly interested in scientific subjects, and kept in touch with the latest discoveries of the day. A voracious reader with a retentive memory, his spare time was occupied with the assimilation of a store of knowledge, the variety and scope of which was remarkable.

At all times fond of travel, the first few months of his emancipation from business were occupied with a tour in India, and it was on a second tour in the East a few months later that he fell a victim to dysentery at Yokohama. A. A. G. T.

JAMES HEYWOOD, M.A., F.R.S., the last surviving brother of the late Sir Benjamin Heywood, died at his residence in Kensington Palace Gardens, London, on October 17, 1897. He was born at Everton on May 28, 1810, being the fourth and youngest son of Mr. Nathaniel Heywood and of Ann, daughter of Dr. Thomas Percival, one of the founders of this Society. His early education was received in Manchester, and continued later at Bristol (under the Rev. Lant Carpenter), Edinburgh and Geneva. He then entered Heywoods' Bank in Manchester, but, in 1829, after the death of his uncle Mr. B. A. Heywood who had bequeathed him considerable property, he withdrew and entered Trinity College, Cambridge. In the Mathematical Tripos of 1833 his name appeared among the Senior Optimes, but, being a nonconformist, he did not graduate on account of the religious test then enforced. This serious impediment he was in later years the main instrument in removing by promoting the Cambridge University Reform Bill, which was passed in 1856, and under which he proceeded to the degree in 1857. For some years he represented North Lancashire in the House of Commons, and was a liberal in politics.

Mr. Heywood was greatly interested in matters relating to the spread of education, and was one of the founders of the Manchester Athenæum, of which he was the first president, and laid the foundation stone of the building. A marble medallion

of him by John Adams Acton was placed in the newsroom of the Athenæum in 1881. It forms one of a group of three, the others representing Richard Cobden and William Langton, who were associated with him in founding the institution.

Mr. Heywood was one of the Trustees of the Owens College by the terms of John Owens' Will, and was, for some years, the president of Manchester New College. For several years when that institution was seated in Manchester, he maintained at his own expense a lecturer in Civil Engineering in connexion with the secular side of the College, the lectures being delivered in a room in his own house in Mosley Street. He was nominated by the Crown to the Senate of the University of London, and there advocated the regulations allowing women to take degrees in that University.

His scientific work was mainly statistical, and the list of his communications to the Statistical Society is a long one. He also wrote on the South Lancashire Coal District, and was elected a Fellow of the Royal Society, February 7, 1859. He was, with R. W. Binney, H. M. Ormerod and G. W. Ormerod, one of the founders of the Manchester Geological Society, and accommodated its collections in his house in Mosley Street, situated where the Clarendon Club now stands, until they were transferred to the ground floor of the left wing of the Museum of the Natural History Society in Peter Street. During a long and active life, he held the positions of President of the Statistical Society and of the Economic Section of the British Association, and Chairman of the Royal Historical Society, and was a member of the first Council of the Chetham Society.

Mr. Heywood married, in 1853, Anne, daughter of John Kennedy of Ardwick and widow of Albert Escher of Zürich, who died in 1872, and by whom he had one daughter. At the time of his death, Mr. Heywood was the "father" of the Society, the date of his election as a member being April 26, 1833.

JOHN RAMSBOTTOM, born at Todmorden on September 11th, 1814, owed his success to his natural aptitude and industry,

and to the opportunities wisely afforded him by his father, who owned a steam-driven cotton mill, and not to a systematic early education. He had constructed many machines in his father's workshop, and had invented the weft fork or weft stopper, which is still essential for the high speed of looms, before, in 1829, he came to Manchester and entered the service of Messrs. Sharp, Roberts and Co. His industry and ability attracted the notice of Mr. C. F. Beyer, who, in 1842, recommended his appointment as locomotive superintendent of the then Manchester and Birmingham Railway. In 1857, he followed Mr. Trevithick as locomotive superintendent at the Crewe Works, and, in 1862, he obtained the control of all the locomotive works of the Company which were then concentrated at Crewe. His inventions in the construction and working of locomotives are too numerous to mention here; the best known are his device for enabling locomotives to pick up water from a trough on the permanent way, and the well-known type of express engine in use on the London and North-Western line. Thirteen papers in the *Proceedings of the Institute of Mechanical Engineers* contain the details of his inventions. He retired from the service of the London and North-Western Railway Company, owing to ill health, in 1871, but, his health being again established, he became consulting engineer at the Horwich Works of the Lancashire and Yorkshire Railway Company in 1883, and was elected a director of that company in 1885. Mr. Ramsbottom was also a director of the firm of Messrs. Beyer, Peacock and Co., and his name is associated with that of Mr. Beyer in connection with the Engineering Department of the Owens College. He was a Governor of the Owens College and a generous contributor to the funds of that institution, apart from his connection with the Department of Engineering.

Mr. Ramsbottom was elected a member of the Society on February 7th, 1854. He died on May 20th, 1897, being in his eighty-third year.

NOTE.—The Treasurer's Accounts of the Session 1897-98 of which the following pages are summaries, have been endorsed as follows:—

April 18th, 1898. Audited and found correct.

We have also seen, at this date, the certificates of the following Stocks held in the name of the Society, viz., £1,225 Great Western Railway Company 5% Consolidated Preference Stock, Nos. 12,293, 12,294, and 12,323; £258 Twenty years' loan to the Manchester Corporation, redeemable 25th March, 1914 (No. 1564); £3,000 Gas Light and Coke Company [London] Certificate No. 47,544, Ordinary A Consolidated Stock, Transfer No. 73,627, th July, 1895; and the Deeds of the Natural History Fund and of the Wilde Endowment Fund, as well as the deeds conveying the land on which the Society's premises stand, and the Declaration of Trust.

(*Signed*)

FRANK SOUTHERN.
THOMAS THORP.

MANCHESTER LITERARY AND

Dr. *J. J. Ashworth, Treasurer, in Account with the*

	£ s. d.	£ s. d.
To Cash in hand, April 1st, 1897		
To Members' Subscriptions :—		375 4 11
Half Subscriptions, 1894-95, 1 at £1 10s. 0d.	1 1 0	
" 1896-97, 3 " "	3 3 0	
" 1897-98, 3 " "	3 3 0	
Subscriptions :— 1891-92, 1 at £2 10s. 0d.	2 2 0	
" 1892-93, 1 " "	2 2 0	
" 1893-94, 3 " "	6 6 0	
" 1894-95, 3 " "	6 6 0	
" 1895-96, 8 " "	16 16 0	
" 1896-97, 27 " "	56 14 0	
" 1897-98, 109 " "	228 18 0	
" 1898-99, 1 " "	2 2 0	
To Wilde Endowment Fund :—		334 19 0
Half Subscriptions, 1895-96, 7 at £1 10s. 0d.	7 7 0	
Subscriptions, 1897-98, 3 " £2 10s. 0d.	6 6 0	
Admission Fees	12 12 0	
To Donation :—		26 5 0
G. A. James Rothney, Esq.		2 10 0
To Contributions from Sections :—		
Microscopical and Natural History Section, 1897-98	5 5 0	
Physical and Mathematical Section, 1897-98	2 2 0	
To Use of the Society's Rooms :—		7 7 0
Transfer from Wilde Endowment Fund, 1897-98		50 0 0
To Sale of Publications		16 6 10½
To Dividends :—		
Natural History Fund	59 4 2	
Joule Memorial Fund	7 9 10	
To Income Tax Refunded :—		66 14 0
Natural History Fund	2 0 10	
Joule Memorial Fund	0 5 0	
		2 5 10
To Bank Interest		1 19 0
		£383 11 0
1898.—April 1. To Cash in Williams Deacon and Manchester & Salford Bank, and in hand		£191 11 7

WILDE ENDOWMENT

	£ s. d.
To Balance from 1896-97	63 4 2
To Dividends on £3,000 Gas Light and Coke Company (London) Ordinary (A) Stock	369 15 0
To Remission of Income Tax, 1897	12 15 0
To Bank Interest	0 17 10
	£446 7 0

NATURAL HISTORY

	£ s. d.
To Dividends on £1,125 Great Western Railway Company's Stock	59 4 2
To Remission of Income Tax, 1897	2 0 10
To Balance against this Fund, April 1st, 1898	93 11 10
	£154 16 10

JOULE MEMORIAL

	£ s. d.
To Balance, April 1st, 1897	23 0 2
To Dividends on £258 Loan to Manchester Corporation	7 9 10
To Remission of Income Tax 1897	0 5 0
	£30 15 0

PHILOSOPHICAL SOCIETY.

Society, from 1st April, 1897, to 31st March, 1898. **Cr.**

	£ s. d.	£ s. d.
By Balance of Wilde Endowment Fund, transferred to District Bank		63 4 2
By Charges on Property :—		
Chief Rent (Income Tax deducted)	12 9 8	
Income Tax on Chief Rent	0 8 7	
Insurance against Fire	13 17 6	
Repairs to Building, &c.	75 5 1	
		102 0 10
By House Expenditure :—		
Coals, Gas, Electric Light, Water, Wood, &c.	24 5 5	
Tea, Coffee, &c., at Meetings	12 0 11½	
Cleaning, Sweeping Chimneys, &c.	5 10 4	
		41 16 8½
By Administrative Charges :—		
Housekeeper	62 8 0	
Postages, and Carriage of Parcels and of "Memoirs"	38 9 10	
Stationery, Cheques, Receipts, and Engrossing	7 16 4½	
Printing Circulars, Reports, &c.	11 19 0	
Legal Charges	2 2 0	
Miscellaneous Expenses	7 4 3	
		129 19 5½
By Publishing :—		
Honorarium for Editing the "Memoirs," 1897-8	50 0 0	
Printing "Memoirs and Proceedings"	120 6 0	
Binding "Memoirs"	2 0 0	
Wood Engraving and Lithography (except Natural History Plates)	11 4 6	
		183 10 6
By Library :—		
Books and Periodicals (except on Natural History)	45 15 0	
Library Appliances	3 5 9	
Binding Repairs	0 8 6	
Expenses of Delegate to Library Conference	5 14 11	
		55 4 2
By Natural History Fund :—		
(Items shown in the Balance Sheet of this Fund)		116 3 7
By Joule Memorial Fund :—		
(No expenditure this session.)		
By Balance at Bank	186 11 7	
,, ,, in Treasurer's hands	5 0 0	
		191 11 7
		£883 11 0

FUND, 1897—1898.

	£ s. d.	£ s. d.
By Assistant Secretary's Salary, April, 1897, to March, 1898		120 0 0
By Maintenance of Society's Library :—		
Periodicals (to complete sets)	78 14 2	
Binding Books in Library	38 7 9	
Catalogue Cabinet	13 0 0	
		130 1 11
By Decorating and Electrical Repairs		22 9 7
By Gold Medal and Engraving Medals		20 19 0
By Wilde Premium		15 15 0
By Honorarium to Lecturer		15 15 0
By Transfers to the Society's Funds :—		
Subscriptions of Members	13 13 0	
Entrance Fees	12 12 0	
Use of Society's Rooms	50 0 0	
		76 5 0
By Cheque Book		0 2 6
By Balance, April 1st, 1897		44 19 0
		£446 7 0

FUND, 1897—1898,

	£ s. d.
By Balance against, April 1st, 1897	38 13 3
By Natural History Books and Periodicals	97 5 7
By Plates for Papers on Natural History in "Memoirs"	18 18 0
	£154 16 10

FUND, 1897—1898.

	£ s. d.
(No Expenditure this Session)	
By Balance, April 1st, 1898	30 15 0
	£30 15 0

Annual Report of the Council of the Microscopical and Natural History Section.

The Council have much pleasure in stating that the Session 1897-98 has been an exceedingly successful one, a large number of very interesting and valuable papers and exhibits having been brought to the meetings.

Several new Associates have been elected, who have added great strength to the Section, and have made valuable contributions to the proceedings, whilst, on the other hand, no resignations have been received.

The papers and exhibits brought to the meetings have generally been more than there was time to read and examine, the principal contributions being by the PRESIDENT, Messrs. MELVILL, BAILEY, CAMERON, BUTTERWORTH, SYKES, ROGERS, HYDE, ALLEN, and BROADBENT.

With the increase in the number of Associates your Council have every reason to look forward to the next session with confidence.

THE COUNCIL

AND MEMBERS

OF THE

MANCHESTER

LITERARY AND PHILOSOPHICAL SOCIETY.

(Corrected to September 30th, 1898.)

President.

JAMES COSMO MELVILL, M.A., F.L.S.

Vice-Presidents.

OSBORNE REYNOLDS, M.A., LL.D., F.R.S.
ARTHUR SCHUSTER, Ph.D., F.R.S., F.R.A.S.
CHARLES BAILEY, F.L.S.
W. H. JOHNSON, B.Sc.

Secretaries.

R. F. GWYTHER, M.A.
FRANCIS JONES, F.C.S., F.R.S.E.

Treasurer.

J. J. ASHWORTH.

Librarian.

W. E. HOYLE, M.A., M.Sc., M.R.C.S.

Of the Council.

HAROLD B. DIXON, M.A., F.R.S.
HORACE LAMB, M.A., F.R.S.
FRANCIS NICHOLSON, F.Z.S.
J. E. KING, M.A.
R. L. TAYLOR, F.C.S.
F. J. FARADAY, F.L.S.

ORDINARY MEMBERS.

Date of Election.

1870, Dec. 13. Angell, John, F.C.S., F.I.C. 6, *Beaconsfield, Derby Road, Withington, Manchester.*

1896, Jan. 21. Armstrong, Frank. *The Remens, Harbord' Grove, Harbord' Road, Ashton-on-Mersey, Cheshire.*

1895, Jan. 8. Armstrong, Geo. B. *Clarendon, Sale, Cheshire.*

1887, Nov. 16. Ashworth, J. Jackson. 39, *Spring Gardens, Manchester.*

1865, Nov. 14. Bailey, Charles, F.L.S. *Ashfield, College Road, Whalley Range, Manchester.*

1888, Nov. 13. Bailey, G. H., D.Sc., Ph.D. *Owens College, Manchester.*

1888, Feb. 7. Bailey, Alderman Sir W. H. *Sale Hall, Sale, Cheshire.*

1895, Jan. 8. Barnes, Charles L., M.A., 10, *Nelson Street, Chorlton-on-Medlock, Manchester.*

1894, Jan. 9. Beckett, J. Hampden, F.C.S. *Corbar Hall, Buxton.*

1896, April 14. Behrens, George B. *The Acorns, 4, Oak Drive, Fallowfield, Manchester.*

1895, Mar. 5. Behrens, Gustav. *Holly Royde, Withington, Manchester.*

1868, Dec. 15. Bickham, Spencer H., F.L.S. *Underdown, Ledbury.*

1896, April 14. Bindloss, James B. *Elm Bank, Eccles, Lancs.*

1896, April 28. Bolton, Herbert, F.R.S.E. 94, *Dickenson Road, Rusholme, Manchester.*

1861, Jan. 22. Bottomley, James, D.Sc., B.A., F.C.S. 220, *Lower Broughton Road, Manchester.*

1896, Oct. 6. Bowman, F. H., D.Sc., F.R.S.E. *Mayfield, Knutsford, Cheshire.*

1896, Feb. 18. Bowman, George, M.D. 594, *Stretford Road, Old Trafford, Manchester.*

1875, Nov. 16. Boyd, John. *Barton House, Didsbury Park, Didsbury, Manchester.*

1889. Oct. 15. Bradley, Nathaniel, F.C.S. *Sunnyside, Whalley Range, Manchester.*

1894, Mar. 6. Broadbent, G. H., M.R.C.S. 8, *Ardwick Green, Manchester.*

1896, Nov. 17. Broderick, Lonsdale, F.C.A. *Somerby, Wilmslow, Cheshire.*

1861, April 2. Brogden, Henry, F.G..S, M.Inst.M.E. *Hale Lodge, Altrincham, Cheshire.*

1889, April 16. Brooks, Samuel Herbert. *Slade House, Levenshulme, Manchester.*

1844, Jan. 23. Brooks, Sir William Cunliffe, Bart, M.A. *Bank, 92, King Street, Manchester.*

1860, Jan. 24. Brothers, Alfred, F.R.A.S. 78, *King Street, Manchester.*

1886, April 6. Brown, Alfred, M.A., M.D. *Sandycroft, Higher Broughton, Manchester.*

Date of Election.

1846, Jan. 27. Browne, Henry, M.A. (Glas.), M.R.C.S. (Lond.), M.D. (Lond.) *The Gables, Victoria Park, Manchester.*

1889, Jan. 8. Brownell, T. W., F.R.A.S. 64, *Upper Brook Street, Manchester.*

1889, Oct. 15. Budenberg, C. F., M.Sc., M.Inst.M.E. *Bowdon Lane, Marple, Cheshire.*

1872, Nov. 12. Burghardt, Charles Anthony, Ph.D. 35, *Fountain Street, Manchester.*

1896, Nov. 3. Burke, John, B.A. *Owens College, Manchester.*

1894, Nov. 13. Burton, Wm., F.C.S. *The Hollies, Clifton Junction, near Manchester.*

1893, Jan. 10. Chadwick, W. I. 26, *King Street, Manchester.*

1854, April 18. Christie, Richard Copley, M.A., *Ribsden, near Bagshot, Surrey.*

1895, April 9. Claus, Wm. H. 31, *Mauldeth Road, Fallowfield, Manchester.*

1895, April 30. Collett, Edward Pyemont. 7, *Wilbraham Road, Chorlton-cum-Hardy, Manchester.*

1884, Nov. 4. Corbett, Joseph. *Town Hall, Salford.*

1895, April 30. Cornish, James Edward. *Stone House, Alderley Edge, Cheshire.*

1859, Jan. 25. Coward, Edward, Assoc.Inst.C.E., M.Inst.M.E. *Heaton House, Heaton Mersey, near Manchester.*

1895, Nov. 12. Crossley, Wm. J., M.Inst,M.E., *Openshaw, Manchester.*

1896, Nov. 3. Crowther, J., A.R.S.M. *Technical School, Swansea.*

1876, April 18. Cunliffe, Robert Ellis. *Halton Bank, Pendleton, Manchester.*

1853, April 19. Darbishire, Robert Dukinfield, B.A., F.S.A. 1, *St. James's Square, Manchester.*

1895, April 9. Dawkins, Wm. Boyd, M.A., F.R.S., Professor of Geology. *Owens College, Manchester.*

1894, Mar. 6. Delépine, Sheridan, M.D., Professor of Pathology. *Owens College, Manchester.*

1879, Mar. 18. Dent, Hastings Charles, F.L.S., F.R.G.S. 20, *Thurloe Square, London, S.W.*

1887, Feb. 8. Dixon, Harold Bailey, M.A., F.R.S., Professor of Chemistry. *Owens College, Manchester.*

1896, Oct. 20. Drey, Oscar. *Carill Drive, Fallowfield, Manchester.*

1883, Oct. 2. Faraday, F. J., F.L.S., F.S.S. *Ramsay Lodge, Slade Lane, Levenshulme, Manchester.*

1897, Oct. 19. Faraday, Wilfred B., LL.B. *Ramsay Lodge, Slade Lane, Levenshulme, Manchester.*

Date of Election.

1895, April 30. Flux, A. W., M.A., Professor of Political Economy. 57, *Parsonage Road, Withington, Manchester.*

1897, Nov. 30. Freston, H. W. 6, *St. Paul's Road, Kersal, Manchester.*

1886, Feb. 9. Gee, W. W. Haldane, B.Sc. *Technical School, Princess Street, Manchester.*

1896, Nov. 17. Gordon, Rev. Alexander, M.A. *Memorial Hall, Albert Square, Manchester.*

1881, Nov. 1. Greg, Arthur. *Eagley, near Bolton.*

1897, Jan. 26. Grossman, J., Ph.D. *Harpurhey Chemical Works, Harpurhey, Manchester.*

1875. Feb. 9. Gwyther, Reginald F., M.A., Fielden Lecturer in Mathematics. *Owens College, Manchester.*

1890, Feb. 18. Harker, Thomas. *Brook House, Fallowfield, Manchester.*

1895, Nov. 12. Hartog, Philippe Joseph, B.Sc., F.C.S., Demonstrator in Chemistry. *Owens College, Manchester.*

1890, Nov. 4. Heenan, H., M.Inst.C.E., M.Inst.M.E. *Manor House, Wilmslow Park, Wilmslow, Cheshire.*

1890, Mar. 4. Henderson, H. A. *Eastbourne House, Chorlton Road, Manchester.*

1896, Nov. 17. Henderson, John, B.Sc. *Ash Villa, Marple, Cheshire.*

1889, Jan. 8. Heywood, Charles J. *Chaseley, Pendleton, Manchester.*

1895, Mar. 5. Hickson, S. J., M.A., D.Sc., F.R.S., Professor of Zoology. *Owens College, Manchester.*

1884, Jan. 8. Hodgkinson, Alexander, M.B., B.Sc. 18, *St. John Street, Manchester.*

1896, Nov. 3. Hopkinson, Edward, D.Sc., M.Inst.C.E. *Oakleigh, Timperley, Cheshire.*

1889, Oct. 15. Hoyle, William Evans, M.A., Keeper of the Manchester Museum. *Owens College, Manchester.*

1896, Nov. 17. Jacob, Edwin. 64B, *Hamilton Terrace, London, N.W.*

1870, Nov. 1. Johnson, William H., B.Sc. 26, *Lever Street, Manchester.*

1896, Oct. 20. Jones, A. Emrys, M.D. 10, *St. John Street, Manchester.*

1878, Nov. 26. Jones, Francis, F.R.S.E., F.C.S., *Manchester Grammar School.*

1891, Nov. 17. Joyce, Samuel, Electrical Engineer. *Latchford House, Greenheys Lane, Manchester.*

1886, Jan. 12, Kay, Thomas. *Moorfield, Stockport, Cheshire.*

1891, Dec. 1. King, John Edward, M.A., High Master, *Manchester Grammar School.*

1895, Nov. 12. Kirkman, W. W. *The Grange, Timperley, Cheshire.*

1893, Nov. 14. Lamb, Horace, M.A., F.R.S., Professor of Mathematics, 6, *Wilbraham Road, Fallowfield, Manchester.*

Date of Election.

1890, Nov. 4. Langdon, Maurice Julius, Ph.D. 15, *Dickinson Street, Manchester.*

1884, April 15. Leech, Daniel John, M.D., Professor of Materia Medica. *Owens College, Manchester.*

1895, Nov. 12. Lees, Charles Herbert, D.Sc., Demonstrator in Physics. *Owens College, Manchester.*

1895, Mar. 5. Levinstein, Ivan. *Wilbraham Road, Fallowfiela, Manchester.*

1857, Jan. 27. Longridge, Robert Bewick, M.Inst.M.E. *Yew Tree House, Tabley, Knutsford, Cheshire.*

1870, April 19. Lowe, Charles, F.C.S. *Summerfield House, Reddish, Stockport, Cheshire.*

1896, Nov. 3. Lynde, James Henry, M.Inst.C.E. *Buckland, Ashton-on-Mersey, Cheshire.*

1866, Nov. 13. McDougall, Arthur, B.Sc. *Fallowfield House, Fallowfield, Manchester.*

1859, Jan. 25. Maclure, Sir John William, Bart., M.P., F.R.G.S. *Whalley Range, Manchester.*

1875, Jan. 26. Mann, John Dixon, M.D., F.R.C.P. (Lond.), Professor of Medical Jurisprudence. 16, *St. John Street, Manchester.*

1896, Oct. 20. Massey, Leonard F. *Openshaw, Manchester.*

1864, Nov. 1. Mather, William, M.Inst.C.E., M.Inst.M.E. *Iron Works, Salford.*

1873, Mar. 18. Melvill, James Cosmo, M.A., F.L.S. *Brook House, Prestwich, Lancs.*

1896, Nov. 3. Milligan, William, M.D. *Westbourne, Wilmslow Road, Rusholme, Manchester.*

1881, Oct. 18. Mond, Ludwig, Ph.D., F.R.S., F.C.S. *Winnington Hall, Northwich, Cheshire.*

1894, Feb. 6. Mond, Robert, M.A., F.C.S. *Winnington Hall, Northwich, Cheshire.*

1873, Mar. 4. Nicholson, Francis, F.Z.S. 84, *Major Street, Manchester.*

1889, April 16. Norbury, George. *Hillside, Prestwich Park, Prestwich, Lancs.*

1862, Dec. 30. Ogden, Samuel. 10, *Mosley Street West, Manchester.*

1884, April 15. Okell, Samuel, F.R.A.S. *Overley, Langham Road, Bowdon, Cheshire.*

1876, Nov. 28. Parry, Thomas, F.S.S. *Grafton House, Ashton-under-Lyne.*

1895, Nov. 12. Pennington, James Dixon, B.A., M.Sc. 254, *Oxford Road, Manchester.*

1892, Nov. 15. Perkin, W. H. jun., Ph.D., F.R.S., Professor of Organic Chemistry. *Owens College, Manchester.*

1885, Nov. 17. Phillips, Henry Harcourt, F.C.S. 183, *Moss Lane East, Manchester.*

Date of Election.

1888, Feb. 21. Rée, Alfred, Ph.D., F.C.S. *Guildhall Chambers, Lloyd Street, Manchester.*

1869, Nov. 16. Reynolds, Osborne, LL.D., M.A., F.R.S., M.Inst.C.E., Professor of Engineering, Owens College. *Ladybarn Road, Fallowfield, Manchester.*

1880, Mar. 23. Roberts, D. Lloyd, M.D., F.R.S.E., F.R.C.P. (Lond.). *Ravenswood, Broughton Park, Manchester.*

1864, Dec. 27. Robinson, John, M.Inst.C.E., M.Inst.M.E. *Westwood Hall, Leek, Staffs.*

1897, Oct. 19. Rothwell, William Thomas. *Heath Brewery, Newton Heath, near Manchester.*

1893, Mar. 21. Schill, C. H. 117, *Portland Street, Manchester.*

1896, Nov. 17. Schmitz, Hermann Emil, B.A., B.Sc. *Manchester Grammar School.*

1842, Jan. 25. Schunck, Edward, Ph.D., F.R.S., F.C.S. *Kersal, Manchester.*

1873, Nov. 18. Schuster, Arthur, Ph.D., F.R.S., F.R.A.S., Professor of Physics. *Owens College, Manchester.*

1898, Jan. 25. Schwabe, Louis. *Hart Hill, Eccles Old Road, Pendleton, Manchester.*

1895, Nov. 12. Shearer, Arthur. 36, *Demesne Road, Alexandra Park, Manchester.*

1890, Nov. 4. Sidebotham, Edward John. *Erlesdene, Bowdon, Cheshire.*

1890, Jan. 21. Sidebotham, James Nasmyth, Assoc.M.Inst.C.E. *Parkfield, Groby Place, Altrincham, Cheshire.*

1886, April 6. Simon, Henry, M.Inst.C.E., M.Inst.M.E., *Lawnhurst, Didsbury, Manchester.*

1895, Nov. 12. Southern, Frank, B.Sc. *Burnage Lodge, Levenshulme, Manchester.*

1896, Feb. 18. Spence, David. *Pine Ridge, Buxton.*

1896, April 14. Stanton, Thomas E., M.Sc. 23, *Kelvin Grove, Princes Park, Liverpool.*

1894, Jan. 9. Stevens, Marshall, F.S.S. *Bolton Lodge, Eccles, Lancs.*

1894, Nov. 13. Stirrup, Mark, F.G.S. *High Thorn, Stamford Road, Bowdon, Cheshire.*

1897, Nov. 30. Stromeyer, C.E., M.Inst.C.E. *Steam Users' Association, 9, Mount Street, Albert Square, Manchester.*

1892, Nov. 29. Swindells, Rupert, M.Inst.C.E. *Wilton Villa, The Firs, Bowdon, Cheshire.*

1895, April 9. Tatton, Reginald A., Engineer to the Mersey and Irwell Joint Committee. 44, *Mosley Street, Manchester.*

1898, Feb. 8. Taylor, Rev. Arthur, M.A. (Oxon.). 49, *Egerton Road, Withington, Manchester.*

Date of Election.

1893, Nov. 14. Taylor, R. L., F.C.S., F.I.C. *Central School, Whitworth Street, Manchester.*

1873, April 15. Thomson, William, F.R.S.E., F.C.S., F.I.C. *Royal Institution, Manchester.*

1896, Jan. 21. Thorburn, William, M.D., B.Sc. 2, *St. Peter's Square, Manchester.*

1889, April 30. Thornber, Harry. *Rookfield Avenue, Sale, Cheshire.*

1896, Jan. 21. Thorp, Thomas. *Moss Bank, Whitefield, near Manchester.*

1897, Jan. 26. Tristram, James Floyd, M.A., B.Sc. 180, *Princess Road, Moss Side, Manchester.*

1879, Dec. 30. Ward, Thomas. *Wadebrook House, Northwich, Cheshire.*

1873, Nov. 18. Waters, Arthur William, F.G.S. *Sunny Lea, Davos Dorf, Switzerland.*

1892, Nov. 15. Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany, Owens College. 4, *Clifton Avenue, Fallowfield, Manchester.*

1895, April 9. Whitehead, James. *Linfield, Fulshaw Park, Wilmslow, Cheshire.*

1859, Jan. 25. Wilde, Henry, F.R.S. *The Hurst, Alderley Edge, Cheshire.*

1859, April 19. Wilkinson, Thomas Read. *Vale Bank, Knutsford, Cheshire.*

1888, April 17. Williams, Sir E. Leader, M.Inst.C.E., M.Inst.M.E. 41, *Spring Gardens, Manchester.*

1896, Dec. 1. Wilson, George, M.Sc. *Owens College, Manchester.*

1889, April 16. Wilson, Thomas B. *Mellor, near Marple, Cheshire.*

1860, April 17. Woolley, George Stephen. *Victoria Bridge, Salford.*

1896, Jan. 21. Wordingham, Charles Henry, A.M.Inst.C.E., M.Inst.M.E. *Hazelhurst, Urmston Lane, Stretford, Manchester.*

1863, Nov. 17. Worthington, Samuel Barton, M.Inst.C.E. M.Inst.M.E. *Mill Bank, Bowdon, and* 37, *Princess Street, Manchester.*

1865, Feb. 21. Worthington, Thomas, F.R.I.B.A. 46, *Brown Street, Manchester.*

1895, Jan. 8. Worthington, Wm. Barton, B.Sc., M.Inst.C.E. 2, *Wilton Polygon, Cheetham Hill, Manchester.*

1897, Oct. 19. Wyatt, Charles H. *Chelford, Cheshire.*

N.B.—Of the above list the following have compounded for their subscriptions, and are therefore life members :—

Bailey, Charles, F.L.S.
Bradley, Nathaniel, F.C.S.
Brogden, Henry, F.G.S.
Johnson, William H., B.Sc.
Lowe, Charles, F.C.S.
Worthington, Wm. Barton, B.Sc.

HONORARY MEMBERS.

Date of Election.

1892, April 26. Abney, W. de Wiveleslie, Capt. R.E., C.B., F.R.S. *Rathmore Lodge, Bolton Gardens South, S. Kensington, London, S.W.*

1892, April 26. Amagat, E. H., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Honorary Professor, Faculty of Sciences, Lyons. 34, *Rue St. Lambert, Paris.*

1894, April 17. Appell, Paul, Membre de l'Institut, Professor at the Faculty of Sciences. *Paris.*

1887, April 19. Armstrong, Wm. George, Lord, C.B., D.C.L., LL.D., F.R.S. *Newcastle-on-Tyne.*

1892, April 26. Ascherson, Paul F. Aug., Professor of Botany. *Berlin.*

1892, April 26. Baeyer, Adolf von, For. Mem. R.S., Professor of Chemistry. 1, *Arcisstrasse, Munich.*

1886, Feb. 9. Baker, Sir Benjamin, K.C.M.G., F.R.S. 2, *Queen's Square Place, Westminster, S.W.*

1886, Feb. 9. Baker, John Gilbert, F.R.S., F.L.S. *Royal Herbarium, Kew.*

1895, April 30. Beilstein, F., Ph.D., Professor of Chemistry, 8th Line, N. 17, *St. Petersburg, W.O.*

1886, Feb. 9. Berthelot, Marcellin, For. Mem. R.S., Membre de l'Institut. Professor of Chemistry. *Paris.*

1892, April 26. Boltzmann, Ludwig, Professor of Physics. *K. K. Universität, Vienna.*

1886, Feb. 9. Buchan, Alexander, M.A., LL.D., F.R.S. 42, *Heriot Row, Edinburgh.*

1860, April 17. Bunsen, Robert Wilhelm, Ph.D., For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Chemistry. *Heidelberg.*

1888. April 17. Cannizzaro, Stanislao, For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Prof. of Chemistry. *University of Rome.*

1889, April 30. Carruthers, William, F.R.S., F.L.S., late Keeper of Botanical Dept., British Museum. *Central House, Central Hill, London, S.E.*

1866, Oct. 30. Clifton, Robert Bellamy, M.A., F.R.S., F.R.A.S., Prof. of Natural Philosophy, Oxford. *New Museum, Oxford.*

1887, April 19. Cornu, Professor Marie Alfred, For. Mem. R.S., Membre de l'Institut. *Ecole Polytechnique, Paris.*

1892, April 26. Curtius, Theodor, Professor of Chemistry. *Kiel.*

Date of Election.

1892, April 26. Darboux, Gaston, Membre de l'Institut, Professor at the Faculty of Sciences. 36, *Rue Gay Lussac, Paris.*

1886, Feb. 9. Dawson, Sir John William, C.M.G., M.A., LL.D., F.R.S., F.G.S. *McGill College, Montreal.*

1894, April 17. Debus, H., Ph.D., F.R.S. 4, *Schlangenweg, Cassel, Hessen, Germany.*

1888, April 17. Dewalque, Gustave, Professor of Geology. *University of Liége.*

1892, April 26. Dohrn, Dr. Anton. *Zoological Station, Naples.*

1892, April 26. Dyer, W. T. Thiselton, C.M.G., C.I.E., M.A., F.R.S., Director of the Royal Botanic Gardens. *Kew.*

1892, April 26. Edison, Thomas Alva. *Orange, N.J., U.S.A.*

1895, April 30. Elster, Julius, Ph.D. 6, *Lessingstrasse, Wolfenbüttel.*

1889, April 30. Farlow, W. G., Professor of Botany. *Harvard College, Cambridge, Mass., U.S.A.*

1889, April 30. Flower, Sir William Henry, K.C.B., LL.D., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 26, *Stanhope Gardens, South Kensington, London, S.W.*

1889, April 30. Foster, Michael, M.A., M.D., LL.D., Sec. R.S., Professor of Physiology. *Trinity College, Cambridge.*

1860, April 6. Frankland, Sir Edward, K.C.B., Ph.D., M.D., LL.D., D.C.L., V.P.C.S., F.R.S., For. Assoc. Inst. Fr. (Acad. Sci.) *The Yews, Reigate Hill, Reigate, Surrey.*

1892, April 26. Friedel, Ch., D.C.L., Membre de l'Institut, Professor at the Faculty of Sciences. 9, *Rue Michelet, Paris.*

1892, April 26. Fürbringer, Max, Professor of Anatomy. *Jena.*

1892, April 26. Gegenbaur, Carl, For. Mem. R.S., Professor of Anatomy. 57, *Leopoldstrasse, Heidelberg.*

1895, April 30. Geitel, Hans. 6, *Lessingstrasse, Wolfenbüttel.*

1892, April 26. Gibbs, J. Willard, For. Mem. R.S., Professor of Mathematical Physics, Yale University. *Newhaven, Connecticut, U.S.A.*

1894, April 17. Glaisher, J. W. L., Sc.D., F.R.S. *Trinity College, Cambridge.*

1894, April 17. Gouy, A., Professor at the Faculty of Sciences. *Lyons.*

1894, April 17. Guldberg, Cato M., Professor of Applied Mathematics. *Christiana, Norway.*

1894, April 17. Harcourt, A. G. Vernon, F.R.S., Lee's Reader in Chemistry, Christ Church. *Cowley Grange, Oxford.*

1894, April 17. Heaviside, Oliver, F.R.S. *Bradley View, Newton Abbots, Devon.*

Date of Election.

1892, April 26. Hermite, Ch., LL.D. (Edin.), For. Mem. R.S., Membre de l'Institut. 2, *Rue de la Sorbonne, Paris.*

1892, April 26. Hill, G.W. *West Nyack, N.Y., U.S.A.*

1888, April 17. Hittorf, Johann Wilhelm, Professor of Physics. *Polytechnicum, Münster.*

1892, April 26. Hoff, J. van't, Ph.D., For. Mem. R.S., Professor of Chemistry. *Amsterdam.*

1892, April 26. Hooker, Sir Joseph Dalton, G.C.S.I., C.B., F.R.S. Corr. Memb. Inst. Fr. (Acad. Sci.) *Sunningdale, Berks.*

1869, Jan. 12. Huggins, Sir William, K.C.B., LL.D., D.C.L., F.R.S., F.R.A.S., Corr. Mem. Inst. Fr. (Acad. Sci.) 90, *Upper Tulse Hill, Brixton, London, S.W.*

1851, April 29. Kelvin, William Thomson, Lord, G.C.V.O., M.A., D.C.L., LL.D., F.R.S., F.R.S.E., For. Assoc. Inst. Fr. (Acad. Sci.), Prof. of Nat. Phil. in Univ. of Glasgow. 2, *College, Glasgow.*

1892, April 26. Klein, Felix, Ph.D., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Mathematics. 3, *Wilhelm Weber Strasse, Göttingen.*

1894, April 17. Königsberger, Leo, Professor of Mathematics. *Heidelberg.*

1895, April 30. Lacaze-Duthiers, F.J. Henri de, For. Mem. R.S., Membre de l'Institut, Prof. à la Sorbonne. 7, *Rue de l'Estrapade, Paris.*

1892, April 26. Ladenburg, A., Ph.D., Professor of Chemistry. 3, *Kaiser Wilhelm Strasse, Breslau.*

1887, April 19. Langley, S. P., For. Mem. R.S. *Smithsonian Institution, Washington, U.S.A.*

1894, April 17. Lie, M. Sophus, For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Mathematics. 33, *Seeburg Strasse, Leipsic.*

1892, April 26. Liebermann, C., Professor of Chemistry. 29, *Matthäi-Kirch Strasse, Berlin.*

1887, April 19. Lockyer, Sir J. Norman, K.C.B., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.) *Science School, Kensington, London, S.W.*

1889, April 30. Lubbock, Sir John, Bart., M.P., D.C.L., LL.D., F.R.S. 15, *Lombard Street, London, E.C.*

1892, April 26. Marshall, Alfred, Sc.D., F.R.S., Professor of Political Economy. *Balliol Croft, Madingley Road, Cambridge.*

1892, April 26. Mascart, E. E. N., For. Mem. R.S., Membre de l'Institut, Professor at the Collège de France. 176, *Rue de l'Université, Paris.*

Date of Election.

1889, April 30. Mendeléeff, D., Ph.D., For. Mem. R.S. *St. Petersburg.*

1895, April 30. Mittag-Leffler, Gösta, D.C.L. (Oxon.), For. Mem. R.S., Professor of Mathematics. *Djursholm, Stockholm.*

1892, April 26. Moissan, H., Membre de l'Institut, Professor at the Ecole Supérieure de Pharmacie. 7, *Rue Vauquelin, Paris.*

1894, April 17. Murray, Sir John, K.C.B., LL.D., D.Sc., F.R.S. *Challenger Lodge, Wardie, Edinburgh.*

1894, April 17. Neumayer, Professor G., Director of the Seewarte. *Hamburg.*

1887, April 19. Newcomb, Simon, For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Mathematics and Astronomy. *Johns Hopkins University, Baltimore, U.S.A.*

1894, April 17. Ostwald, W., Professor of Chemistry. 2/3, *Linnéstrasse, Leipsic.*

1892, April 26. Perkin, W. H., LL.D., Ph.D. F.R.S. *The Chestnuts, Sudbury, Harrow.*

1894, April 17. Pfeffer, W., For. Mem. R.S., Professor of Botany. *Botanisches Institut, Leipsic.*

1892, April 26. Poincaré, H., For. Mem. R.S., Membre de l'Institut, Professor at the Faculty of Sciences. 63, *Rue Claude Bernard, Paris.*

1892, April 26. Quincke, G. H., For. Mem. R.S., Professor of Physics, 60, *Hauptstrasse, Heidelberg.*

1892, April 26. Raoult, F. M., Corr. Memb. Inst. Fr. (Acad. Sci.), Dean of the Faculty of Sciences. 2, *Rue des Alpes, Grenoble.*

1849, Jan. 23. Rawson, Robert, F.R.A.S. *Havant, Hants.*

1886, Feb. 9. Rayleigh, John William Strutt, Lord, M.A., D.C.L. (Oxon.), LL.D. (Univ. McGill), F.R.S., F.R.A.S. Corr. Memb. Inst. Fr. (Acad. Sci.) *Tiyling Place, Witham, Essex.*

1897, April 27. Roscoe, Sir Henry Enfield, B.A., LL.D., D.C.L., F.R.S., F.C.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 10, *Bramham Gardens, Wetherby Road, London, S.W.*

1889, April 30. Routh, Edward John, Sc.D., F.R.S. *Newnham Cottage, Cambridge.*

1894, April 17. Rowland, Henry A., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Physics. *Johns Hopkins University, Baltimore, U.S.A.*

Date of Election.

1889, April 30. Salmon, Rev. George, D.D., D.C.L., LL.D., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.) *Provost's House, Trinity College, Dublin.*

1894, April 17. Sanderson, J. S. Burdon, M.A., M.D., F.R.S., Regius Professor of Medicine. *Oxford.*

1892, April 26. Sharp, R. Bowdler, LL.D. *British Museum (Natural History), Cromwell Road, London, S.W.*

1892, April 26. Solms, H. Graf zu, Professor of Botany. *Strassburg.*

1869, Dec. 14. Sorby, Henry Clifton, LL.D., F.R.S., F.G.S. *Broomfield, Sheffield.*

1851, April 29. Stokes, Sir George Gabriel, Bart., M.A., LL.D., D.C.L., F.R.S., F.C.P.S., Corr. Mem. Inst. Fr. (Acad. Sci.), Lucasian Professor of Mathem. Univ. Cambridge. *Lensfield Cottage, Cambridge.*

1886, Feb. 9. Strasburger, Eduard, D.C.L., For. Mem. R.S., Professor of Botany. *Bonn.*

1895, April 30. Suess, Eduard, Ph.D. For. Mem. R.T., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Geology. 9, *Africanergasse, Vienna.*

1868, April 28. Tait, Peter Guthrie, M.A., F.R.S.E, Professor of Natural Philosophy, Edinburgh. 38, *George Square, Edinburgh.*

1895, April 30. Thomson, Joseph John, M.A., Sc.D., F.R.S., Professor of Experimental Physics. 6, *Scrope Terrace, Cambridge.*

1894, April 17. Thorpe, T. E., Ph.D., F.R.S. *Laboratory, Somerset House, London, W.C.*

1894, April 17. Turner, Sir William, M.B., D.C.L., F.R.S., Professor of Anatomy. 6, *Eton Terrace, Edinburgh.*

1886, Feb. 9. Tylor, Edward Burnett, D.C.L. (Oxon.), LL.D. (St. And. and McGill Colls.), F.R.S, Keeper of University Museum. *Oxford.*

1894, April 17. Vines, Sidney Howard, M.A., D.Sc., F.R.S., Sherardian Professor of Botany. *Headington Hill, Oxford.*

1894, April 17. Waage, P., Professor of Chemistry. *Christiania, Norway.*

1894, April 17. Warburg, Professor E. *Physikalisches Institut, Neue Wilhelmstrasse, Berlin.*

1894, April 17. Ward, H. Marshall, Sc.D., F.R.S., Professor of Botany. *Cooper's Hill, Englefield Green, Surrey.*

1894, April 17. Weismann, August, Professor of Zoology. *Freiburg-i.-B.*

1892, April 26. Wiedemann, G. H., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Prof. of Physics. 35, *Thalstrasse, Leipsic.*

1889, April 30. Williamson, Alexander William, Ph.D., LL.D., F.R.S., Corr. Mem. Inst. Fr. (Acad. Sci.) *High Pitfold, Shottermill, Haslemere, Surrey.*

Date of Election.

1886, Feb. 9. Young, Charles Augustus, Professor of Astronomy. *Princeton College, N.J., U.S.A.*

1888, April 17. Zirkel, Ferdinand, For. Mem. R.S., Professor of Mineralogy. *University of Leipsic.*

1895, April 20. Zittel, Carl Alfred von, Professor of Palæontology and Geology. *University of Munich.*

CORRESPONDING MEMBERS.

Date of Election.

1866, Jan. 23. De Caligny, Anatole, Marquis, Corr. Mem. Accad. Sci. Turin, Soc. Agr. Lyons, Soc. Sci. Cherbourg. *Liége.*

1850, April 30. Harley, Rev. Robert, Hon. M.A. (Oxon.), F.R.S., F.R.A.S., Hon. M.R.S. Queensland. *Rosslyn, Westbourne Road, Forest Hill, London, S.E.*, and *The Athenæum Club, London, S.W.*

1882, Nov. 14. Herford, Rev. Brooke. 91, *Fitzjohn's Avenue, Hampstead, London, N.W.*

1859, Jan. 25. Le Jolis, Auguste-François, Ph.D., Archiviste-perpétuel and late President of the Soc. Nat. Sci. Cherbourg. *Cherbourg.*

1857, Jan. 27. Lowe, Edward Joseph, F.R.S., F.R.A.S., F.G.S., Mem. Brit. Met. Soc. *Shirenewton Hall, near Chepstow, Monmouthshire.*

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1897. Sir WILLIAM HUGGINS, K.C.B., F.R.S.

1898. Sir JOSEPH DALTON HOOKER, G.C.S.I., C.B., F.R.S.

Award of the Dalton Medal.

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1898. JOHN BUTTERWORTH, F.R.M.S.

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1897-98.

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II. Description of two New Species of Mutilla from South Africa. By Peter Cameron . . . . . pp. 1—3

III. On Waves in a Medium having a Periodic Discontinuity of Structure. By Horace Lamb, M.A., F.R.S. . . . . pp. 1—20

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